1972

Viscoplastic behavior of plates with finite deflections.

Stefanidis, Spyridon.

Massachusetts Institute of Technology

VISCOPLASTIC BEHAVIOR OF PLATES WITH FINITE DEFLECTIONS

Spyridon Stefanidis

"VISCOPLASTIC BEHAVIOR OF PLATES WITH FINITE DEFLECTIONS"

By

SPYRIDON STEFANIDIS

LIEUTENANT, HELLENIC NAVY

1961

SUBMITTED IN PARTIAL FULFILLMENT

OF THE REQUIREMENTS FOR THE

DEGREE OF MASTER OF SCIENCE

IN NAVAL ARCHITECTURE AND MARINE ENGINEERING

AND THE DEGREE OF MASTER OF SCIENCE

IN MECHANICAL ENGINEERING

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

May, 1972

ACKNOWLEDGMENTS

The author wishes to express his gratitude to his thesis supervisor, Professor Norman Jones, for his advice, encouragement, patience and understanding.

He is also indebted to Captain W. R. Porter, USN, for his invaluable help and guidance, academic and other.

The author also wants to thank Professor Lardner who kindly made himself available as Mechanical Engineering Department Reader and Messrs. I. Constantopoulos and S. Anagnostopoulos for their help with part of the computations.

Thanks are due to Miss Jane Greeley whose expert typing rendered the thesis its final form.

However, above all, the author is grateful to his wife and his parents for their moral support which provided the motivation toward his graduate education.

ABSTRACT

A theoretical investigation is developed herein in order to estimate the permanent transverse deflections of rectangular plates when subjected to large dynamic loads. The influence of finite deflections or geometry changes and of strain-rate sensitivity is retained in the analysis but elastic effects are disregarded. The particular case of a fully clamped plate acted on by a uniformly distributed pressure pulse is studied in detail. It is observed that good agreement between the theoretical predictions and experimental results has been obtained for rectangular plates made from strain-rate sensitive material.

Thesis Supervisor
Professor Norman Jones
May, 1972

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

NOTATION

B	Semi-width of plate
D	Material constant defined by equation (2)
H	Thickness of plate
I	$p_o \tau$
I'	$p_o \tau / (\mu H p_c)^{1/2}$
L	Semi-length of plate
M_o	Static limiting plastic moment = $\frac{\sigma_o H^2}{4}$
M'_o	Dynamic limiting plastic moment, defined by equations (4a-d)
N_o	Static limiting plastic axial force = $\sigma_o H$
N'_o	Dynamic limiting plastic axial force, defined by equations (4a-d)
T, T_1	Durations of parts of the response
V_o	Initial velocity
W_m	Permanent transverse deflection
W_f	Permanent transverse deflection if $\gg H$
p	Material constant defined by equation (2)
p_c	Magnitude of static collapse pressure
p_i, p_3	External pressures per unit surface area of a plate
p_o	Magnitude of dynamic pressure pulse
t, t_2, t_3	Time
w	Transverse deflection of the midplane of a plate
x, x', y	Co-ordinates defined in figure 2
z	Co-ordinate which is perpendicular to the mid-plane of an initially flat plate
β	$\frac{B}{L}$
ε_{ij}	Direct strain
η	$\frac{P_o}{P_c}$

$\dot{\theta}_m$	Relative angular rotation rate across a line hinge
K_{ij}	Curvature
	Mass per unit area of plate
ξ_o	$\tan\phi$
	Non-dimensional times
σ_o	Yield stress
τ	Duration of a rectangular pressure pulse
	angle defined in figure 2
$(\dot{\ })$	$\frac{\partial}{\partial t}$
ε_o	Strain at middle axis of plate's section

INTRODUCTION

In reference [1] Jones investigated the influence of finite deflections on the behavior of arbitrarily shaped plates and beams which are subjected to large dynamic loads. In his analysis Jones disregarded any elastic effects, strain-hardening and rate sensitivity. It has been shown that elastic effects can be neglected in the computation of final deformation if the kinetic energy input is appreciably larger than the maximum elastic strain energy the plate can absorb. With respect to material properties, experiments have indicated that strain rate sensitivity is by far the most important property neglected in rigid-perfectly plastic methods. Thus, while experiments with rate insensitive materials, such as Aluminium Al6061T6, show remarkable agreement with theoretical results, in the case of mild steel, a notoriously rate sensitive material, significant disagreement between theory and experiment takes place, the net result being an underestimation on the ability of a plate to sustain a given dynamic load. Cowper and Symonds [3, 8] and Symonds and Jones [4] have developed an approximate theoretical method to examine the influence of rate sensitivity in beams. Their results show drastic improvement, as compared with experimental evidence, over the non-rate sensitive methods.[2, 5]

A general approximate theoretical procedure, which retains both finite deflections and strain rate sensitivity, is presented herein for the dynamic behavior of arbitrarily shaped, rigid-perfectly plastic plates. This procedure is essentially an extension of the one developed by Jones [1] in order to include strain rate effects. The particular case of a fully clamped rectangular plate subjected to a uniformly distributed dynamic pressure pulse is studied in more detail.

APPROXIMATE ANALYSIS

In reference [1] Jones shows that if a plate (or beam) is divided into a number of rigid regions separated by r straight line hinges, each of length lm, then an energy balance yields the following relation:

$$\int_A (p_3 - \mu\ddot{w})\,\dot{w}\,dA = \sum_{m=1}^{r} \int_{lm} (Nw - M)\,\dot{\theta}m\,d\ell m \qquad (1)$$

where w is the transverse deflection at the hinge.

The stresses at the hinges due to the axial force N and bending moment M act on a plane which is parallel to the hinge and transverse to the midplane of the plate. $\dot{\theta}m$ is the relative angular rotation rate across the hinge and is supposed to be infinitesimal. The quantity $(Nw - M)\,\dot{\theta}m$, on the right hand side of equation (1), represents the internal energy dissipation per unit length of a hinge. This dissipation function will depend on the boundary conditions of a plate and on the yield condition used.

For a strain rate sensitive material Symonds and Jones in reference [3] represent the dependence of the dynamic lower yield stress $\sigma(\dot{\varepsilon})$ on the plastic strain rate $\dot{\varepsilon}$ by the following:

$$\frac{\sigma(\dot{\varepsilon})}{\sigma_0} = 1 + \left(\frac{\dot{\varepsilon}}{D}\right)^{\frac{1}{p}} \qquad (2)$$

where σ_0 is the static yield stress, and p and D are material constants. This relation is totally empirical and approximate, providing good representation of test results up to strain rates in the neighborhood of 1,000 sec^{-1}. If formula (2) is used to derive dynamic plastic bending moment and axial force for rate sensitive behavior, assuming the Navier hypothesis valid, Symonds and Jones [4] show that:

(see next page)

$$\frac{M}{Mo'} = 1 - \frac{4z^2}{H^2} \qquad (4a)$$

$$\frac{N}{No'} = 2\frac{z}{H} \qquad (4b)$$

where $Mo' = \left[1 + \frac{2p}{2p+1} \left(\frac{\dot{K} H}{2D}\right)^{1/p} \right] Mo$

$No' = \left[1 + \left(\frac{\dot{K} H}{2D}\right)^{1/p} \right] No$

and $z \leqslant \frac{H}{2}$

$$\frac{M}{M_o'} \simeq \frac{1}{2p+1} \cdot \frac{H}{2Z}$$

$$\frac{N}{N_o'} = 1$$

where $M_o' = \left[1 + \left(\frac{\varepsilon_o}{D}\right)^{1/p} \right] M_o$

$N_o' = \left[1 + \left(\frac{\varepsilon_o}{D}\right)^{1/p} \right] N_o$

and $z \geqslant \frac{H}{2}$

$\dot{K}$ = curvature rate

z = distance between middle and neutral axes of the plate's cross-section.

The moment Mo' and axial force No' are to be interpreted as the dynamic equivalents of the static values Mo, No.

When equations (4a) and (4b) are combined they give the yield condition:

$$\frac{|M|}{Mo'} = 1 - \left(\frac{N}{No'}\right)^2 \qquad \text{YIELD CONDITION} \qquad (5)$$

This condition is the maximum normal stress yield criterion, parabolic in shape, as is seen in figure 1.

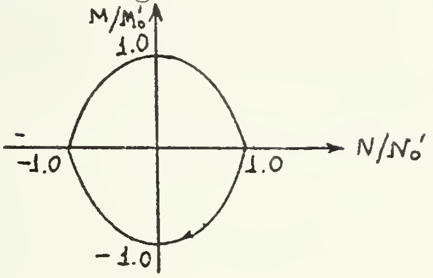

figure 1

It should be pointed out that equation (1) has been derived for arbitrarily shaped plates and since it is an energy balance equation, it can be used with any kind of edge conditions, provided that plastic hinges are allowed to form around the boundary of the plate, if necessary, as well as the interior.

If a kinematically admissible collapse mechanism with straight line hinges is postulated, then equation (1), combined with the appropriate relations for $(Nw - M)\dot{\theta}m$, can be solved to give an estimate of the influence of finite-deflections and strain rate on the deflection-time history of rigid, perfectly plastic plates (or beams) loaded dynamically.

DYNAMIC BEHAVIOR OF A FULLY CLAMPED RECTANGULAR PLATE

From infinitesimal plasticity analyses it is evident that the shape of the displacement field of a beam or plate for small dynamic loads is the same as the static collapse velocity profile [1,2]. In addition, from experimental results [2,5] it is seen that the permanent deformed profiles of rectangular plates loaded dynamically are similar to the shape of the velocity field used by Wood[6] in static analysis.

Consider a rigid, perfectly plastic rectangular plate of length 2L and width 2B, fully clamped around its outer boundary, as shown in figure 2. The plate is subject to a uniformly distributed dynamic load with the pressure-time history shown in figure 3.

This external loading may be expressed in the form:

$$p_3 = p_o \quad \text{for} \quad 0 \leqslant t \leqslant \tau \tag{6a}$$

$$p_3 = 0 \quad \text{for} \quad \tau \leqslant t \leqslant T + \tau \tag{6b}$$

where τ and $(T + \tau)$ are the durations of the pressure pulse and the plate response, respectively.

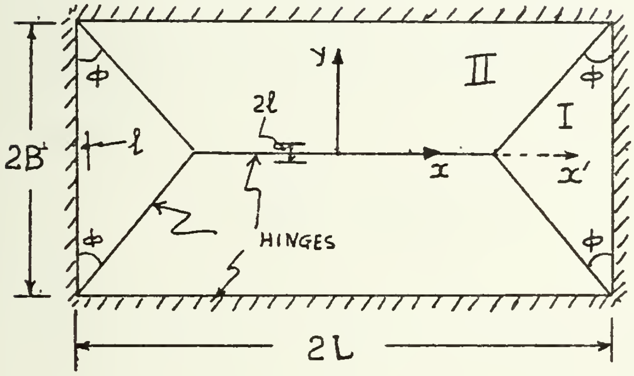

figure 2

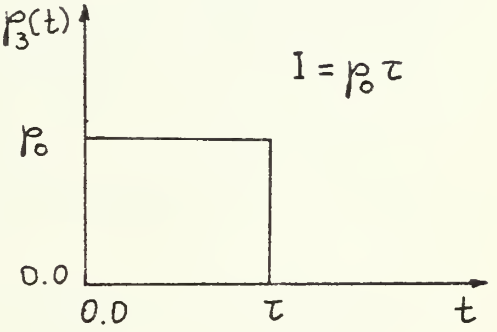

figure 3

Assuming Wood's displacement field, as discussed above, we have:

$$w = \frac{W_i (B \tan\phi - x')}{B \tan\phi} \tag{7a}$$

for region I

and:

$$w = \frac{W_i (B - y)}{B} \tag{7b}$$

for region II. Regions I and II are indicated in figure 2 and i = 1 refers to the deflections during the time imterval $0 \leqslant t \leqslant \tau$, while i = 2 refers to $\tau \leqslant t \leqslant T + \tau$.

In order to use equation (1), its right hand side is examined first, Thus:

(see next page)

$$\sum_{m=1}^{\sqrt{}} \int_{lm} (Nw - M)\,\dot{\theta}m \, d\,lm = 4 \int_{o}^{\frac{B}{\cos\phi}} (Nw - M)\,\dot{\theta}m \frac{dx'}{\sin\phi} +$$

$$+ 2 \int_{o}^{L-B\tan\phi} (Nw - M)\,\dot{\theta}m \, dx + 4 \int_{o}^{L} (Nw - M)\,\dot{\theta}m \, dx + 4 \int_{o}^{B} (Nw - M)\,\dot{\theta}m \, dy \qquad (8)$$

The evaluation of the right hand side of equation (8) requires the use of equations (7a, and 7b) together with the yield condition and the relations:

$$Mo = \frac{\sigma o\ H^2}{4} \quad , \qquad No = \sigma oH$$

Values for the curvature rate $\dot{K}$, rotation rate $\dot{\theta}m$ and hinge width to be used in each integral are given in table (1).

	1st Integral	2nd Integral	3rd Integral	4th Integral
$\dot{\theta}m$	$\frac{\dot{W}1}{B\ \sin}$	$\frac{2\dot{W}1}{B}$	$\frac{\dot{W}1}{B}$	$\frac{\dot{W}1}{B\ \tan}$
$\dot{K}$	$\frac{\dot{W}1}{2B1\ \sin}$	$\frac{\dot{W}1}{B1}$	$\frac{\dot{W}1}{B1}$	$\frac{\dot{W}1}{B1\ \tan}$
Hinge Width	21	21	1	1

Table (1)

It should be pointed out that in the third and fourth integrals $w = 0$.

If the above information together with equations (6a), (7a) and (7b) are substituted into equation (1) then it is straightforward to show that: (see next page)

$$\ddot{W}_1 + (h_1 W_1^2 + h_2)\, \dot{W}_1^{1/p} + h_3 W_1^2 = d_1 \qquad (9)$$

where: $0 \leqslant t \leqslant \tau$, $W \leqslant H$

$$h_1 = \frac{b_5}{b_1} , \quad h_2 = \frac{b_4}{b_1} , \quad h_3 = \frac{b_2}{b_1} , \quad d_1 = \frac{b_3 - 1}{b_1}$$

$$b_1 = \frac{\mu B^2}{12\ Mo} \frac{(2 - b \tan\phi)}{(1 + b \cot\phi)} \quad ; \qquad b = \frac{B}{L}$$

$$b_2 = \frac{1}{3H^2} \left[1 + 2 \frac{(1 - b \tan\phi)}{(1 + b \cot\phi)} \right.$$

$$b_3 = \frac{Po}{Pc} \equiv \eta , \qquad Pc = \frac{12\ Mo}{B^2} \frac{(1 + b \cot\phi)}{(3 - b \tan\phi)}$$

$$b_4 = \frac{A_1\ b}{(1 + b \cot\phi)}$$

$$b_5 = \frac{A_2\ b}{3H^2 (1 + b \cot\phi)}$$

$$A_1 = \frac{C_2\ L}{B} - \frac{C_2 \sin^2\phi + C_1 + C_3 \cos^2\phi}{2 \sin\phi \cos\phi}$$

$$A_2 = \frac{3C_2\ L}{B} - \frac{3C_2 \tan\phi + 3C_1 - C_2 \sin^2\phi - C_3 \cdot \cos^2\phi}{2 \sin\phi \cos\phi}$$

$$C_2 = \frac{2p}{2p+1} \left(\frac{H}{2\ B1D}\right)^{1/p}$$

$$C_1 = \frac{2p}{2p+1} \left(\frac{H}{4\ B1D \sin\phi}\right)^{1/p}$$

$$C_3 = \frac{2p}{2p+1} \left(\frac{H}{2\ B1D \tan\phi}\right)^{1/p}$$

and $\tan\phi = \sqrt{3 + b^2} - b$ to ensure smallest upper bound to the actual static collapse pressure.[5]

Equation (9) obviously is very difficult to solve analytically. Given the fact that the whole procedure herein is an approximate one, and aiming at providing the designers with relatively simple results, a drastic simplification will be made by setting $p = 1$, $D = 500\ \text{sec}^{-1}$, albeit the proper values of p and D for mild steel are 5 and 40 respectively. Thus, the highly non-linear equation (2) is linearized. Even so, however, it is hoped that the whole procedure will give sufficient insight into the behavior of strain rate sensitive plates.

Now equation (9) may be recast as:

$$\ddot{W}_1 + (h_1 W_1^2 + h_2)\dot{W} + h_3 W_1^2 = d_1 \tag{9a}$$

A series solution to equation (9a) employing the method of undetermined coefficients, and which satisfies the initial conditions $W_1 = \dot{W}_1 = 0$ at $t = 0$, yields the results:

$$W_1 = \overline{W}_1$$

and $$\dot{W}_1 = \overline{\dot{W}}_1$$

at the end of the first stage of motion $(t = \tau)$, where:

$$\bar{W}_1 = \frac{d_1 \tau^2}{2} \left[1 - \frac{h_2 \tau}{3} + \frac{h_2^2 \tau^2}{12} - \frac{h_2^3 \tau^3}{60} + \frac{h_2^4 \tau^4}{360} - \right.$$

$$- \frac{d_1 h_3 \tau^4}{60} + \frac{h_3 d_1 \tau^5}{420} - \frac{h_2^4 \tau^5}{2520} + \frac{h_2 h_3 d_1 \tau^5}{126} -$$

$$\left. - \frac{h_1 d_1^2 \tau^5}{84} \right] \tag{9b}$$

$$\dot{\bar{W}}_1 = d_1 \tau \left[1 - \frac{h_2 \tau}{2} + \frac{h_2^2 \tau^2}{6} - \frac{h_2^3 \tau^3}{24} + \frac{h_2^4 \tau^4}{120} - \right.$$

$$- \frac{h_3 d_1 \tau^4}{20} + \frac{h_3 d_1 \tau^5}{120} - \frac{h_2^4 \tau^5}{720} +$$

$$\left. + \frac{h_2 h_3 d_1 \tau^5}{36} - \frac{h_1 d_1^2 \cdot \tau^5}{24} \right] \tag{9c}$$

A study of the second stage of motion ($\tau \leqslant t \leqslant T + \tau$) proceeds in a manner similar to that outlined above for the first stage, but with equations (9b) and (9c) as initial conditions, and with $\eta = 0$.

Thus the differential equation to be solved now is:

$$\ddot{W}_2 + (h_1 W_2^2 + h_2) \dot{W}_2 + h_3 W_2^2 = d_2 \tag{10}$$

where $d_2 = \frac{-1}{b1}$; $(\dot{\ }) = \frac{d}{dt_1}$

A series solution to equation (10) employing the method of undetermined coefficients and satisfying equations (9b) and (9c) gives the maximum value of the transverse deflection of the permanently deformed plate as:

$$\frac{W_m}{H} = \frac{W_2(T)}{H} = \frac{\overline{W}_1}{H} + \frac{\dot{\overline{W}}_1 \rho}{H} + \frac{\alpha_2 \tau^2 \rho^2}{H} + \frac{\alpha_3 \tau^3 \rho^3}{H} + \frac{\alpha_4 \tau^4 \rho^4}{H}$$

where: $\alpha_2 = \frac{d_2}{2} - \frac{1}{2}(h_2 + h_1 \overline{W}_1^{\,2})\dot{\overline{W}}_1 - \frac{1}{2} h_3 \overline{W}_1^{\,2}$

$$\alpha_3 = -\frac{1}{3}\left[\alpha_2 (h_2 + h_1 \overline{W}_1^{\,2}) + (h_3 + h_1 \dot{\overline{W}}_1)\overline{W}_1 \dot{\overline{W}}_1\right]$$

$$\alpha_4 = -\left[2\alpha_2 \overline{W}_1 \cdot (3h_1 \dot{\overline{W}}_1 + h_3) + 3\alpha_3 (h_2 + h_1 \overline{W}_1^{\,2}) + \right.$$

$$\left. + (h_3 + h_1 \dot{\overline{W}}_1)\dot{\overline{W}}_1^{\,2}\right]$$

and $\rho = \frac{T}{\tau}$ is the smallest non-negative root of the polynomial equation:

$$4\alpha_4 \tau^3 \rho^3 + 3\alpha_3 \tau^2 \rho^2 + 2\alpha_2 \tau \rho + \dot{\overline{W}}_1 = 0 \qquad (12)$$

Equation (12) is obtained from the requirement that $\dot{W}_1 = 0$ at $t_1 = T$ where t_1 refers to second stage alone.

Equation (11) remains valid provided $\frac{W_m}{H} \leqslant 1$, because when $\frac{W_m}{H} \geqslant 1$ the dissipation expressions $(Nw - M)\dot{\theta}m$ take on new values (since then $N = No'$ and $M = 0$) on those portions of the hinge lines which have transverse deflections greater than the plate thickness. In this case, a time dependent rectangular boundary travels outwards from the central line hinge toward the edge of the plate. This boundary always has a deflection $W = H$ and divides the plate into two regions:

an inner zone with $W > H$ and an outer zone with $W < H$. The dissipation relations $(Nw - M)\dot{\theta}m$ must be evaluated in the inner region with $N = No'$, $M = 0$ while in the outer region the evaluation which was used earlier remains unchanged. Figure 4 indicates the two regions:

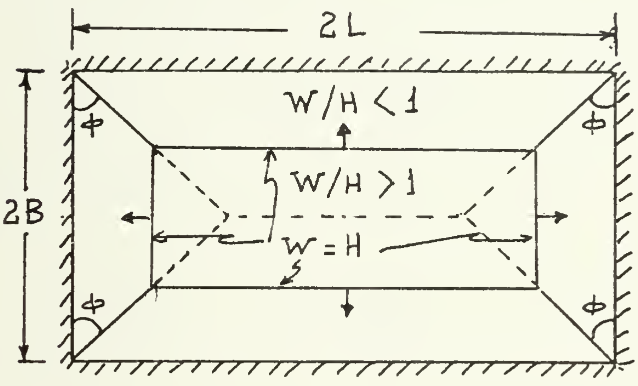

figure 4

If it is assumed that W/H exceeds one when $t \gg \tau$, then the first stage of motion given by equations (9a, b, and c) remains unchanged, while the second stage remains valid until $t = t_2$, when $W/H = 1$ where t_2 is the response time of the second stage alone. Thus, the non-dimensional time $\rho_2 = \frac{t_2}{\tau}$ may be found from equation (11) with $W = H$, i.e.:

$$\alpha_4 \tau^4 \rho_2^4 + \alpha_3 \tau^3 \rho_2^3 + \alpha_2 \tau^2 \rho_2^2 + \dot{\bar{W}}_1 \tau \rho_2 + \bar{W}_1 - H = 0 \quad (13)$$

The smallest non-negative root of (13) gives ρ_2, i.e. the response time for the second stage.

Now all subsequent behavior of the plate will have $W \gg H$ at the centrally located plastic hinge. It is therefore necessary to consider a third stage of motion which is governed by the dissipation relations employing $N = No'$, $M = 0$ where necessary, as discussed earlier. It is quite straightforward to show that in this case the following equation is obtained:

(see next page)

$$\ddot{W}_3 + Z_1 W_3 + \frac{Z_2}{W_3} + Z_3 W_3 \dot{W}_3^{1/p} + Z_4 \frac{\dot{W}_3^{1/p}}{W_3} = 0 \qquad (14)$$

Again the simplification $p = 1$ is employed so that (14) becomes:

$$\ddot{W}_3 W_3 + (Z_3 W_3^2 + Z_4)\dot{W}_3 + Z_1 W_3^2 + Z_2 = 0 \qquad (14a)$$

where $t_2 \leqslant t \leqslant T + t_2$, $p_3 = 0$

$$Z_1 = \frac{\pi_2}{\pi_1}, \quad Z_2 = \frac{\pi_3}{\pi_1}, \quad Z_3 = \frac{\pi_4}{\pi_1}, \quad Z_4 = \frac{\pi_5}{\pi_1}$$

$$\pi_1 = \frac{\mu(2 - \xi_o)}{Pc\,(3 - \xi_o)} \quad ; \quad \xi_o = b \tan\phi$$

$$\pi_2 = \frac{2\,(3 - 3\xi_o + \xi_o^2)}{H\,(3 - \quad o)}$$

$$\pi_3 = \frac{\dot{H} b}{3} \; \frac{(\cot\phi + \tan\phi)}{(1 + b \cot\phi)}$$

$$\pi_4 = \frac{C_2}{H} \; \frac{\left[\,2 - 2\xi_o + \xi_o \left(\frac{2 \sin\phi}{\sin^2\phi}\right)^{-1/p}\,\right]}{(1 + b \cot \quad)}$$

$$\pi_5 = \frac{C_2 b H}{3} \; \frac{\left[\cot\phi\,(\tan\phi)^{-1/p} + \tan\phi\right]}{(1 + b \cot\phi)}$$

A series solution to equation (14a) with the initial conditions $W_3 = H$, $\dot{W}_3 = \dot{\bar{W}}_2$ at $t_3 = 0$, where t_3 is refering to third stage alone, gives:

$$W_3 = H + \dot{\bar{W}}_2 t_3 + \alpha'_2 t_3^2 + \alpha'_3 t_3^3 \qquad (15a)$$

where: $$\alpha'_2 = -\frac{1}{2H}\,[Z_1 H^2 + Z_2 + (Z_4 + Z_3 H^2)\,\dot{\bar{W}}_2\,]$$

$$\alpha'_3 = -\frac{1}{3H}[Z_1 H\dot{\bar{W}}_2 + Z_3 H\dot{\bar{W}}_2^{\;2} + \alpha'_2(\dot{\bar{W}}_2 + Z_4 + Z_3 H^2)]$$

and $$\dot{W}_3 = \dot{\bar{W}}_2 + 2\alpha'_2 t_3 + 3\alpha'_3 t_3^{\;2} \qquad (15b)$$

when $t_3 = T_1$, $\dot{W}_3 = 0$, $W_3 = W_f$

Substituting for T_1 in equation (15b) and retaining its smallest non-negative root, T_1 is obtained, i.e. the response time of the third stage alone. The value of the final and permanent displacement is given then by equation (15a) with $t_3 = T_1$.

$$\frac{Wf}{H} = 1 + \frac{\dot{\bar{W}}_2\, T_1}{H} + \frac{\alpha'_2\, T_1^{\;2}}{H} + \frac{\alpha'_3\, T_1^{\;3}}{H} \qquad (16)$$

where $\dot{\bar{W}}_2$ is obtained from equation (13) by differentiation:

$$\dot{\bar{W}}_2 = \dot{\bar{W}}_1 + 2\alpha_2 \tau \rho_2 + 3\alpha_3 \tau^2 \rho_2^{\;2} + 4\alpha_4 \tau^3 \rho_2^{\;3} \qquad (16a)$$

An alternative approximate solution to equation (14a), for the third stage of motion, which is valid for any value of p, but for only a short range of values of the aspect ratio b, can be obtained as follows:

Call $$W_4 = \frac{W_3}{H}$$

$$Z'_1 = HZ_1\ , \qquad Z'_3 = HZ_3$$

$$Z'_2 = \frac{Z_2}{H}\ , \qquad Z'_4 = \frac{Z_4}{H}$$

$$\alpha_1 = \frac{Z'_1}{Z'_3}, \qquad \alpha_2 = \frac{Z'_2}{Z'_4}$$

Then equation (14a) becomes

$$\ddot{W}_4 + Z'_3 W_4 (\alpha_1 + \dot{W}_4{}^{1/p}) + \frac{Z'_4}{W_4} (\alpha_2 + \dot{W}_4{}^{1/p}) = 0 \quad (17)$$

By inspection the constants α_1 and α_2, which both depend on the aspect ratio b, are approximately equal for $0 \leqslant b \leqslant 0.3$, their ratio varying between 0.98 and 1.16.

Thus, by the substitution $\alpha_1 = \alpha_2 = \alpha$, equation (17) is further transformed to:

$$\frac{\ddot{W}_4}{(\alpha + \dot{W}_4{}^{1/p})} + Z'_3 W_4 + \frac{Z'_4}{W_4} = 0 \qquad (17a)$$

Employing the change of variables

$$\ddot{W}_4 = \dot{W}_4 \frac{d\,\dot{W}_4}{d\,W_4} \quad \text{and integrating:}$$

$$\dot{W}_4{}^{1-1/p}\, d\dot{W}_4 - \frac{1}{\alpha} \Big[\int \dot{W}_4{}^{1-2/p}\, d\dot{W}_4 - \frac{1}{\alpha} [(\dot{W}_4{}^{1-3/p}\, d\dot{W}_4 -$$

$$- \frac{1}{\alpha} \int \dot{W}_4{}^{1-4/p}\, d\dot{W}_4 - \frac{1}{\alpha} (\dot{W}_4{}^{1-5/p}\, d\dot{W}_4 - \frac{1}{\alpha} \int \frac{\dot{W}_4{}^{1-5/p}}{\alpha + \dot{W}_4{}^{1/p}}\, d\dot{W}_4)] +$$

$$+ \frac{Z'_3}{2} W_4^2 + Z'_4 \log_e W_4 + C = 0 \qquad (17b)$$

For mild steel, when p = 5, equation (17b) yields:

(see next page)

$$\frac{1}{2}\alpha^{-7}\dot{W}_4^{\,2} + \left(\frac{5}{4} - \frac{5}{9}\alpha^{-\frac{34}{5}}\right)\dot{W}_4^{\,9/5} + \left(\frac{5}{8}\alpha^{-\frac{33}{5}} - \frac{5}{3}\alpha^{-1}\right)\dot{W}_4^{\,8/5} +$$

$$+\left(\frac{5}{2}\alpha^{-2} - \frac{5}{7}\alpha^{-\frac{32}{5}}\right)\dot{W}_4^{\,7/5} + \left(\frac{5}{6}\alpha^{-\frac{31}{5}} - 5\alpha^{-3}\right)\dot{W}_4^{\,6/5} +$$

$$+\left(\alpha^{-4} - \alpha^{-6}\right)\dot{W}_4 + \frac{Z'_3}{2}W_4^{\,2} + Z'_4\log_e W^4 + C = 0$$

The constant C is evaluated with the conditions:

$$\text{at } t = t_2 \qquad W_4 = \frac{W_3}{H} = 1, \qquad \dot{W}_4 = \frac{\dot{\bar{W}}_2}{H}$$

Then the conditions

$$\text{at } t = T_1 \quad \dot{W}_4 = 0, \quad W_4 = \frac{W_f}{H} \qquad \text{give:}$$

$$\frac{Z'_3}{2}\left(\frac{W_f}{H}\right)^2 + Z'_4\log_e\left(\frac{W_f}{H}\right) = \frac{1}{2}\alpha^{-7}\left(\frac{\dot{\bar{W}}_2}{H}\right)^2 +$$

$$+\left(\frac{5}{4} - \frac{5}{9}\alpha^{-\frac{34}{5}}\right)\left(\frac{\dot{\bar{W}}_2}{H}\right)^{9/5} + \left(\frac{5}{8}\alpha^{-\frac{33}{5}} - \frac{5}{3}\alpha^{-1}\right)\left(\frac{\dot{\bar{W}}_2}{H}\right)^{8/5} +$$

$$+\left(\frac{5}{2}\alpha^{-2} - \frac{5}{7}\alpha^{-\frac{32}{5}}\right)\left(\frac{\dot{\bar{W}}_2}{H}\right)^{7/5} + \left(\frac{5}{6}\alpha^{-\frac{31}{5}} - 5\alpha^{-3}\right)\left(\frac{\dot{\bar{W}}_2}{H}\right)^{6/5} +$$

$$+\left(\alpha^{-4} - \alpha^{-6}\right)\left(\frac{\dot{\bar{W}}_2}{H}\right) + \frac{Z'_3}{2} \qquad (18)$$

The final permanent deflection is given by the root of transcendental equation (18) and can be expected to be within the interval:

(see next page)

$$1 \leqslant \frac{W_f}{H} \leqslant \Bigg[1 + \frac{2}{Z'_3} \Bigg[\frac{1}{2} \alpha^{-7} \left(\frac{\dot{\overline{W}}_2}{H}\right) + \left(\frac{5}{4} - \frac{5}{9} \alpha^{-\frac{34}{5}}\right)\left(\frac{\dot{\overline{W}}_2}{H}\right)^{9/5} +$$

$$+ \left(\frac{5}{8} \alpha^{-\frac{33}{5}} - \frac{5}{3} \alpha^{-1}\right)\left(\frac{\dot{\overline{W}}_2}{H}\right)^{8/5} + \left(\frac{5}{2} \alpha^{-2} - \frac{5}{7} \alpha^{-\frac{32}{5}}\right)\left(\frac{\dot{\overline{W}}_2}{H}\right)^{7/5} +$$

$$+ \left(\frac{5}{6} \alpha^{-\frac{31}{5}} - 5 \alpha^{-3}\right)\left(\frac{\dot{\overline{W}}_2}{H}\right)^{6/5} + \left(\alpha^{-4} - \alpha^{-6}\right)\left(\frac{W_2}{H}\right) \Bigg] \Bigg]^{1/2}$$

DISCUSSION

The approximate method presented in this paper has been used to predict the permanent transverse deflections (Wf/H) presented in Figures (5-9) for fully clamped, rate-sensitive rectangular plates which are subjected to uniformly distributed impulsive loading, i.e. when $p_0\tau = \mu V_o$.

It is evident from figure (5) and tables (2-6, 9) that the estimates which were obtained using equations (11) or (16) and rectangular plates with b = 0.593 agree reasonably well with the corresponding experimental values.

It is apparent from figures (6- 8) that, for a given value of impulse, the permanent transverse deflection of a plate is essentially independent of the magnitude of η when η is larger than 50. It is also noticed that for increasing values of η the deflections slightly decrease, whereas in the non-rate-sensitive analysis of Ref. [1] they are seen to slightly increase. The probable explanation for this difference in behavior could be that in the rate-sensitive case with increasing η the rate-sensitive effects become more pronounced the net result being the (favorable) reduction in Wf/H. However, since for large values of η the deflections are essentially independent of η, as discussed above, for impulsive loading, when $\eta \rightarrow \infty$, this difference in behavior becomes insignificant.

From figures (9, 10) and tables (9-11) it is observed that the value of the permanent deflection is also affected by the value of the hinge width and the value of the material property D. It should be pointed out here that the value of D is merely a value used in equation (2) to describe the $\sigma - \dot{\varepsilon}$ curve for the material. The proper value of D for mild steel is 40 $\sec^{-1}$ when p = 5. The mathematical difficulties that led to the linearization of equation (2) by setting p = 1 naturally have an effect on the value of D as well, thus affecting the final results. However,

it is evident from figure ( ) that for values of D greater than 300 sec^{-1} the variation in Wf/H is rather small so that if D = 300 sec^{-1} is used with the present analysis results good enough for engineering predictions can be obtained. Similarly, the optimum value of the hinge width, which is unknown at the outset, may be seen from figure ( ) to be 1 = 5H. (These observations are made for the particular case of mild steel).

All the theoretical results presented in this paper were obtained by assuming that angular changes across the plastic hinges were sufficiently small to permit $\tan\phi$ to be replaced by θ rad. This simplification provides a good approximation when Wf/H is not too large. Moreover, only the few first terms were retained in the series solutions of the differential equations encountered in the analysis. It would be necessary to consider additional terms for large Wf/H ratios and for cases in which the dynamic to static pressure ratio (η) is small. The yield condition derived in ref [4] and presented here as equation (2) is an approximation to the exact one, though the effect of this approximation is not considered to be important. The linearization of equation (2) by setting p = 1 is considered to be of some importance since then a highly non-linear curve is replaced by a straight line. However, given the fact that the most important factor in dynamic loading of plates is the influence of finite deflections, which are ignored in bending-only methods, this linearization seems to be acceptable, at least tentatively, since the results are reasonably close to experimental values and at the same time a good insight into the rate-sensitive behavior is gained.

The approximate procedure presented in this paper could be used to examine the influence of large transverse dynamic loads on the behavior of beams and plates which have any shape and support conditions, provided the appropriate plastic hinge pattern is postulated.

Finally it should be remarked that the predictions of this analysis are thought to be valid when the external dynamic energy applied to a

beam or plate is appreciably larger than the amount of energy which could be absorbed in an elastic manner.

CONCLUSIONS - RECOMMENDATIONS

An approximate theoretical investigation is developed herein in order to estimate the permanent deflections of rectangular plates and beams subjected to large dynamic loads. The influence of geometry changes and of strain-rate sensitivity is retained in the analysis but no elastic effects are considered. The particular case of a fully clamped rectangular plate acted on by a uniformly distributed pressure pulse is studied in detail. Tables and graphs are provided for the case of fully clamped plates and beams made from mild steel and loaded impulsively. It is observed that good agreement between the theoretical predictions and experimental results has been obtained for a rectangular plate of aspect ratio b = 0.593. Improved theoretical predictions are expected to be obtained if equation (11) is solved for the correct value of p. Though equation (18) is an exact solution to equation (17), it is valid only for a short range of aspect ratios (0 - 0.3) and even in that range it contains some approximations. Moreover, equation (17) corresponds to the third stage of motion only so that the exact solution (18) should not be used unless equation (11) has been solved correctly as well. Exact or numerical solutions to equations (11) and (16) would be a useful complement to this paper.

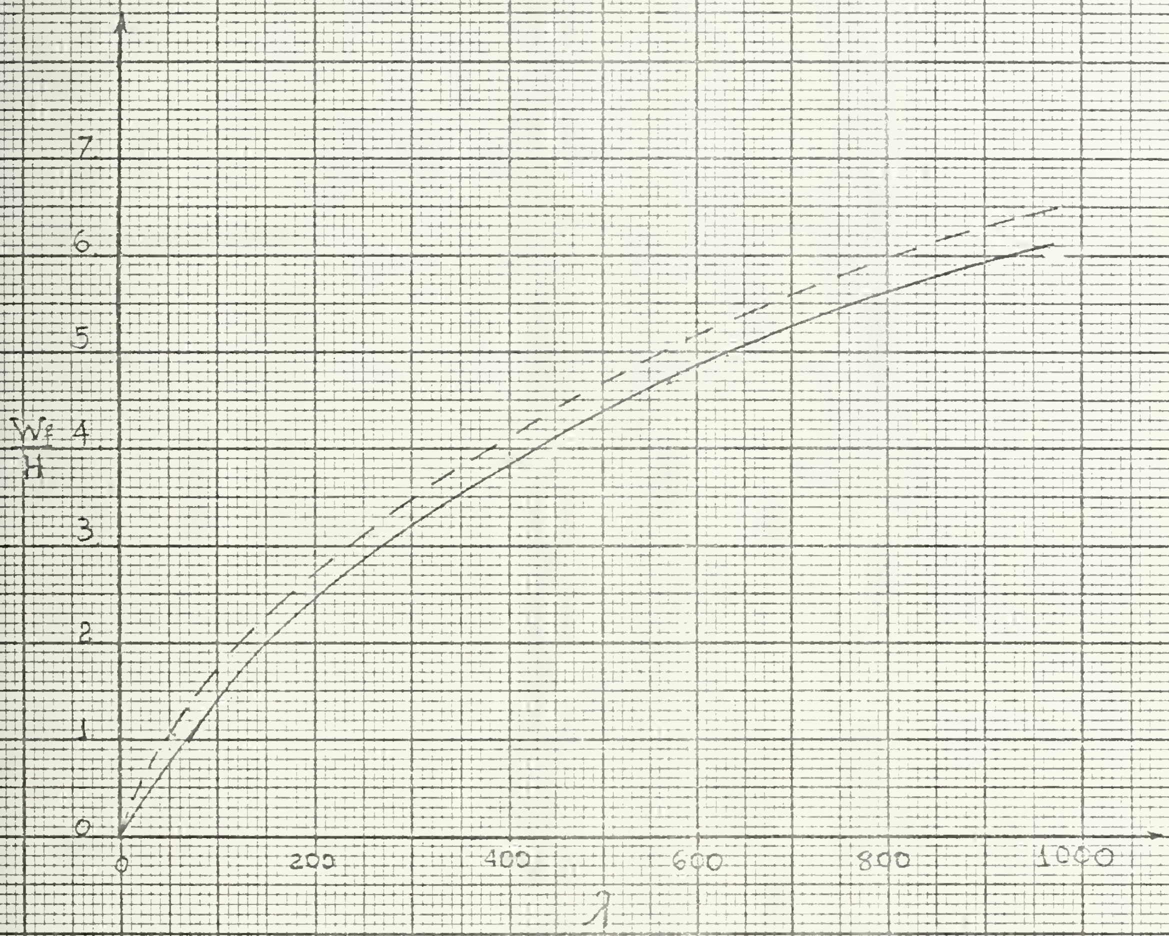

Figure (5) ——— Equation (11) or (16)

Experimental, Ref [2]

— — — b = .523

ASPECT RATIO=.593

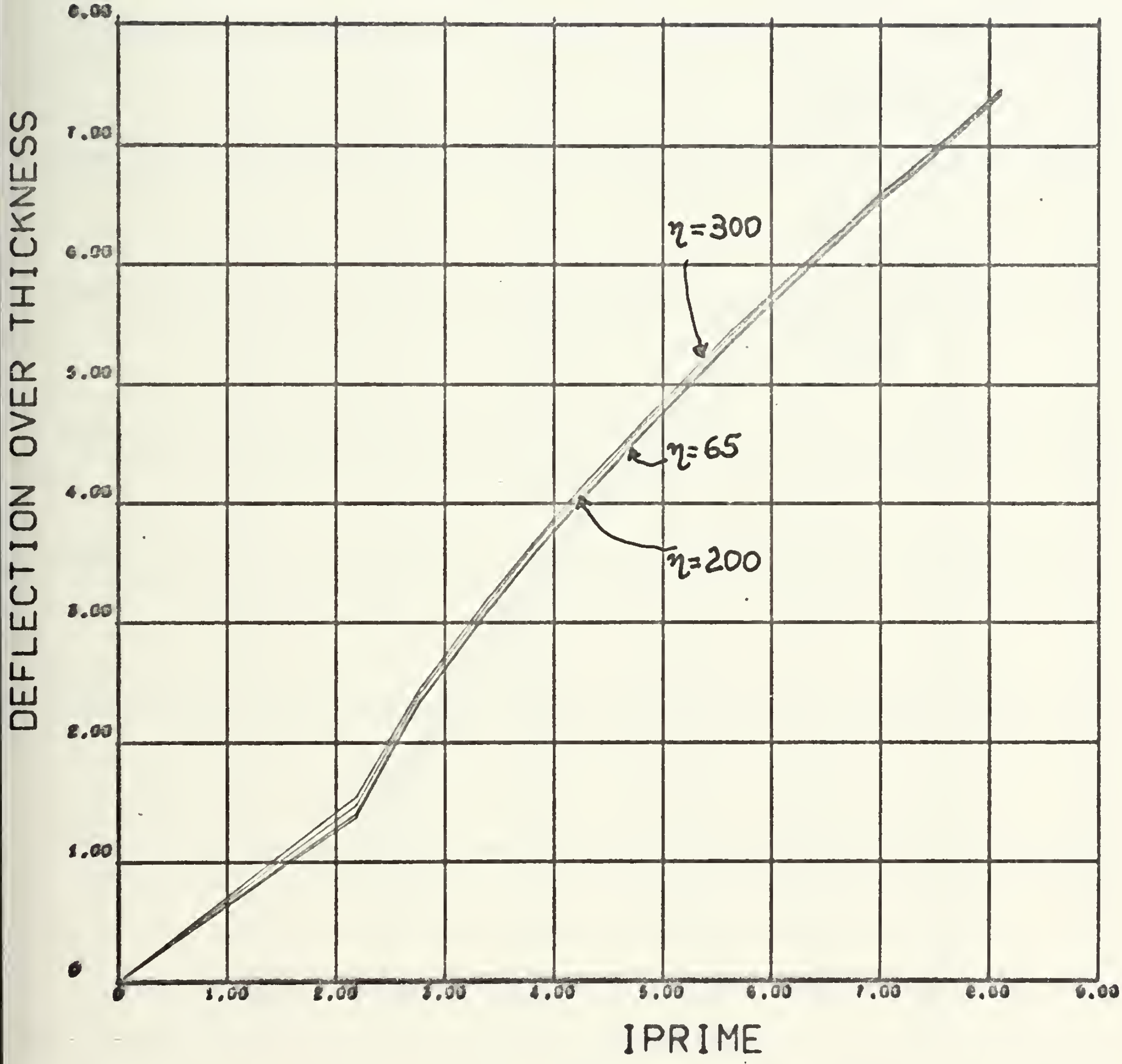

FIG. (6)

ASPECT RATIO=.75

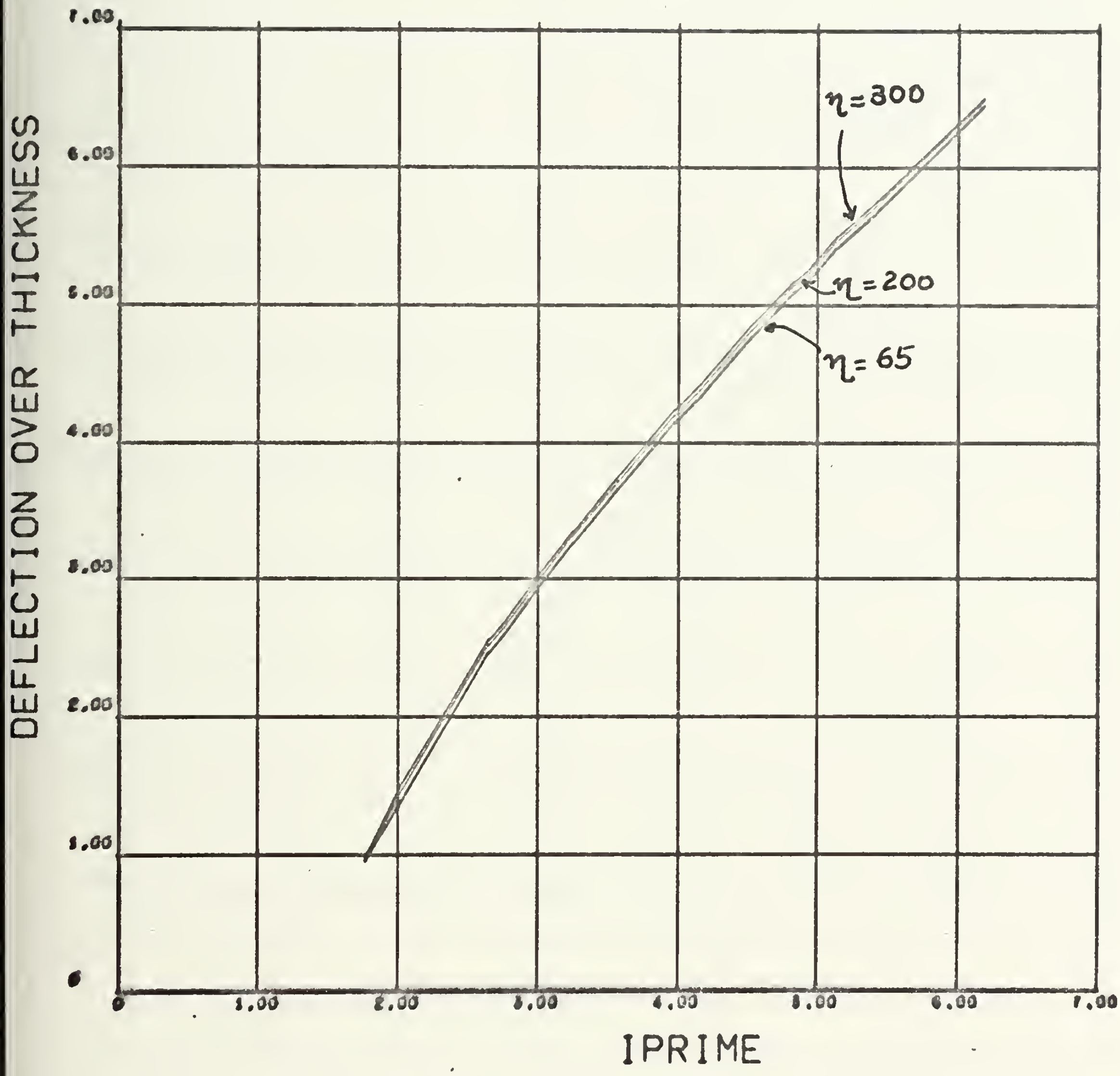

FIG. (7)

ASPECT RATIO=1.0

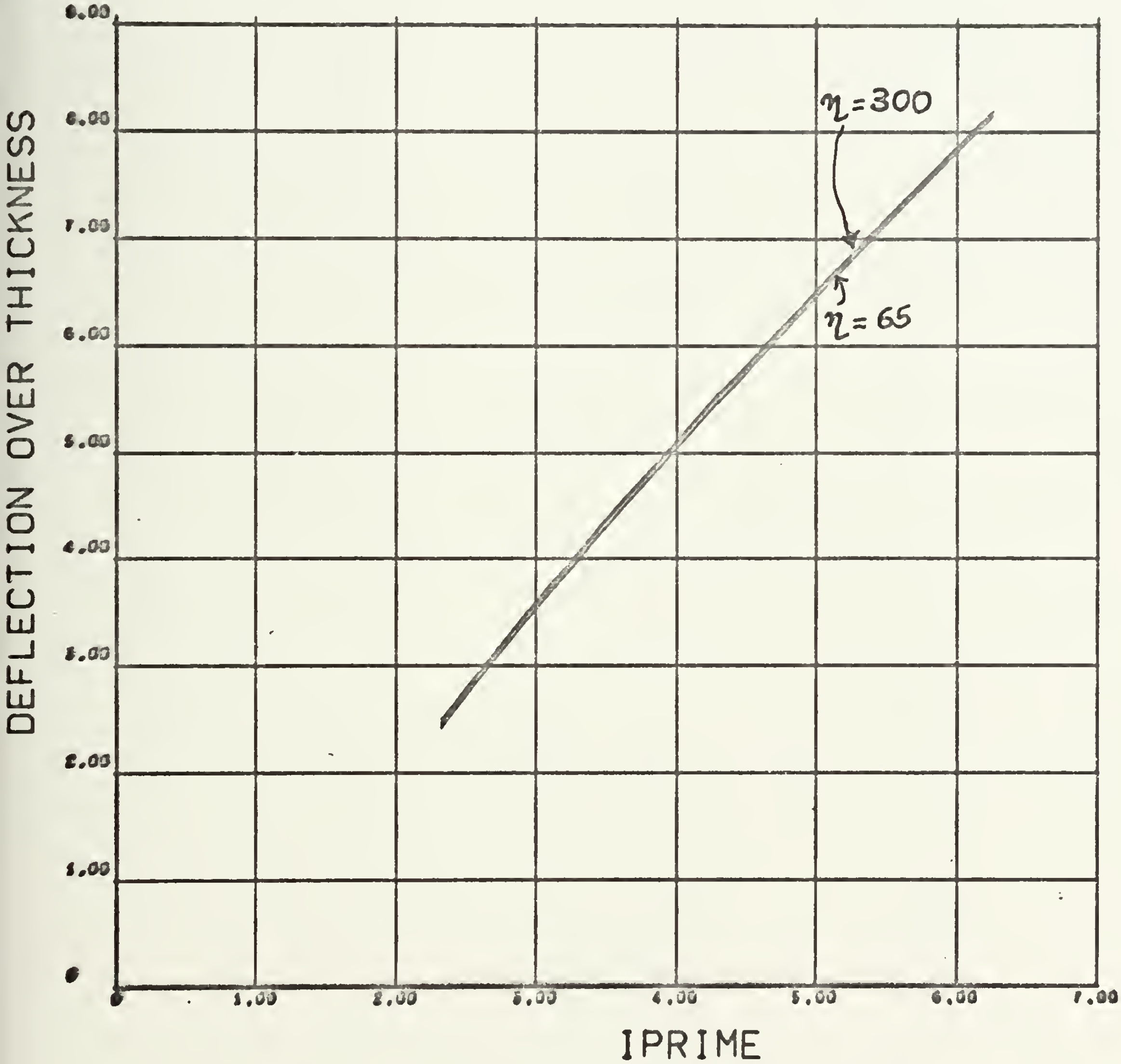

FIG. (8)

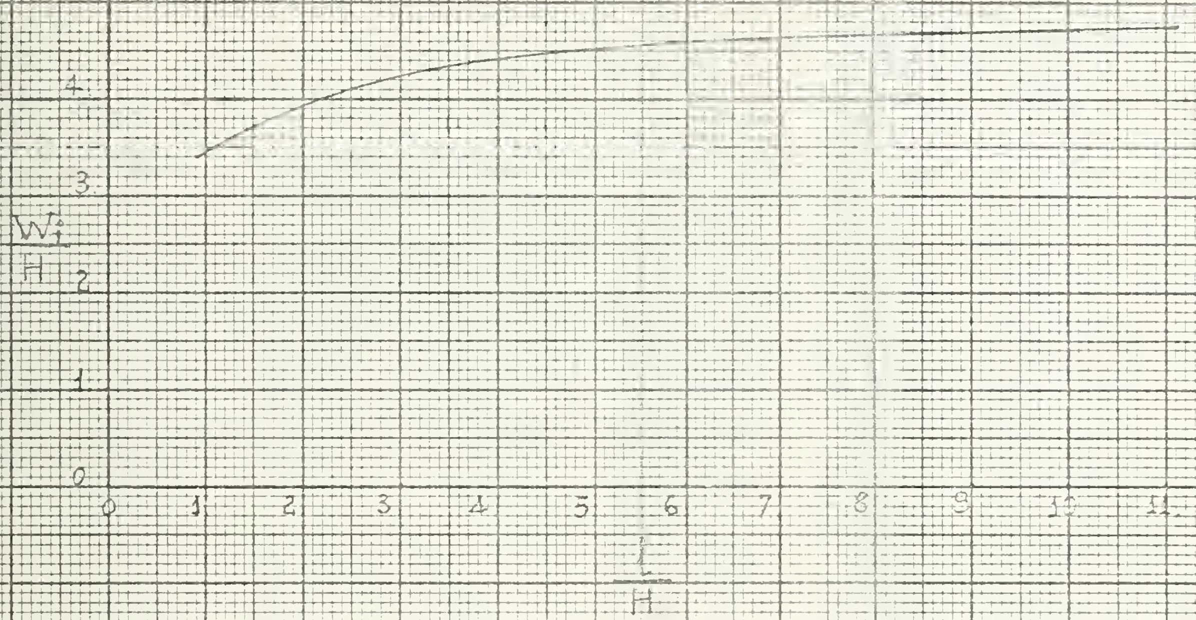

Figure (9)

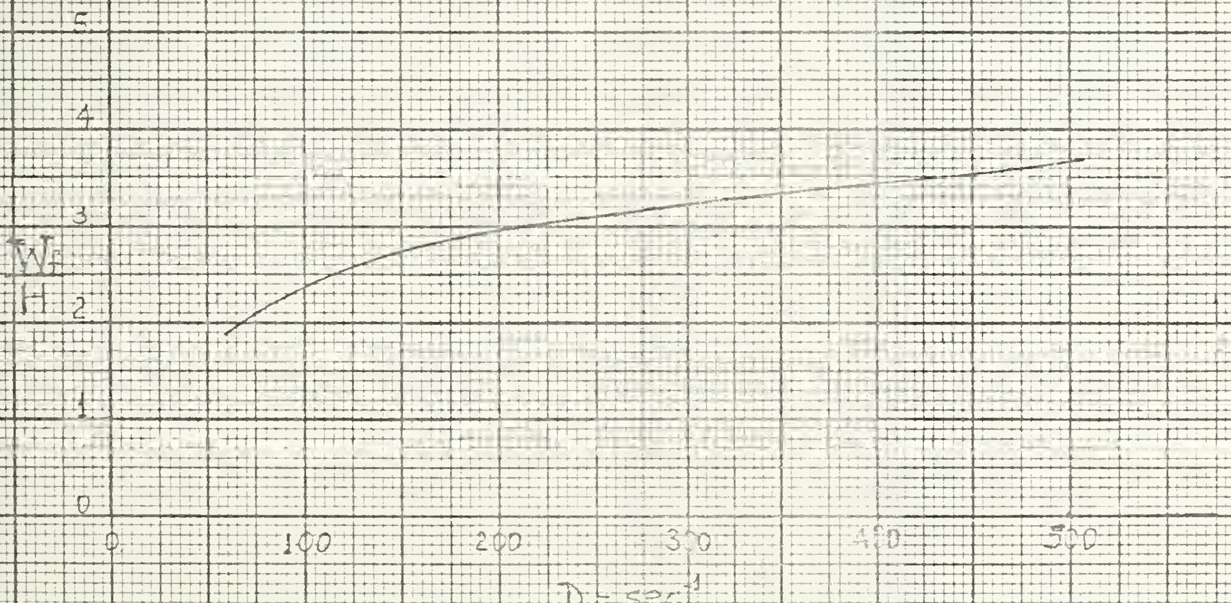

Figure (10)

H-in	Vo-ft/sec		I'	Equation (11)or(16) Wf/H	Experimental Ref [2] Wf/H
.0643	134.08	323.05	3.806	3.682	3.542
.0644	152.60	417.16	4.326	4.253	4.120
.0638	165.06	497.30	4.723	4.684	4.650
.0638	180.06	591.78	5.152	5.123	5.166
.0647	233.00	963.55	6.574	6.458	6.420
.0635	234.08	1009.604	6.730	6.643	6.730
.0998	80.73	51.64	1.522	.771	1.046
.0985	118.95	115.08	2.272	1.515	1.890
.0984	161.70	213.10	3.092	2.690	2.755
.0983	177.90	258.46	3.405	3.053	3.330
.0982	202.60	335.90	3.881	3.564	3.760
.0984	231.13	435.38	4.420	4.096	4.300
.1728	69.69	11.79	.727	.339	.310
.1728	88.85	19.16	.927	.457	.515
.1728	130.90	41.59	1.366	.678	1.022
.1728	153.36	57.09	1.600	.780	1.257
.1728	165.70	66.64	1.730	.833	1.420
.1728	166.26	67.09	1.735	.835	1.411
.1728	171.10	71.06	1.785	.855	1.580
.1728	178.02	76.92	1.857	.883	1.715

Table (2). $b = 0.593$, $l = 5H$, $D = 300 \text{ sec}^{-1}$, $\eta = 200$.

H- in	Vo- ft/sec		Equation (11) or(16) Wf/H	Experimental, Ref [2]. Wf/H
.0643	134.08	232.05	3.562	3.542
.0644	152.60	417.16	4.102	4.12
.0638	165.06	497.30	4.505	4.650
.0638	180.06	591.78	4.915	5.166
.0635	234.08	1009.60	6.318	6.730
.0998	80.73	51.64	.763	1.046
.0985	118.95	115.08	1.431	1.890
.0984	124.20	125.72	1.62	1.940
.0982	177.90	258.98	2.935	3.330
.0982	202.60	335.90	3.412	3.760
.0983	216.70	383.49	3.662	4.135
.0984	231.13	435.38	3.908	4.300
.1728	69.69	11.79	.336	.310
.1728	88.85	19.16	.452	.515
.1725	130.90	41.59	.670	1.022
.1729	165.70	66.57	.816	1.411
.1727	178.02	77.01	.864	1.715

Table (3). Theoretical vs. experimental results. $b = 0.593$, $D = 460\ \text{sec}^{-1}$, $l = 2.5H$, $\eta = 200$.

H-in	Vo-ft/sec		Equation (11)or(16) Wf/H	Experimental Ref [2] Wf/H
.0643	134.08	323.05	3.517	3.542
.0644	152.60	417.16	4.04	4.12
.0638	165.06	497.30	4.443	4.650
.0638	180.06	591.78	4.845	5.166
.0647	233.00	963.55	6.043	6.420
.0635	234.08	1009.60	6.220	6.730
.0998	80.73	51.64	.762	1.046
.0985	118.95	115.08	1.428	1.890
.0984	124.20	125.72	1.586	1.940
.0982	177.90	258.98	2.932	3.330
.0982	202.60	335.90	3.408	3.760
.0983	216.70	383.49	3.658	4.135
.0984	231.13	435.38	3.903	4.300
.1728	69.69	11.79	.332	.310
.1728	88.85	19.16	.443	.515
.1725	130.90	41.74	.647	1.022
.1729	165.70	66.57	.783	1.411
.1727	178.02	77.01	.828	1.715

Table (4). $b = 0.593$, $D = 460\ sec^{-1}$, $\eta = 200$

H-in	Vo-ft/sec		I'	Wf/H
.1728	69.69	11.50	.367	.0747
.1728	88.85	18.69	.486	.1077
.1728	153.36	55.69	.808	.2145
.1729	165.70	64.93	.872	.2327
.1728	166.26	65.45	.876	.2338
.1727	178.02	75.12	.938	.2508

Table (5). Theoretical results for $b = 0.25$, $D = 500 \text{ sec}^{-1}$, $l = 2.5H$, $\eta = 200$.

H-in	Vo-ft/sec		Equation (11)or(16) Wf/H	Experimental Ref [2] Vf/H
.0998	80.73	51.64	.765	1.046
.0985	118.95	115.08	1.459	1.890
.0984	124.20	125.72	1.618	1.940
.0982	177.90	258.98	2.976	3.330
.0983	216.70	383.49	3.718	4.135
.0982	202.60	335.90	3.462	3.760
.0984	231.13	435.38	3.969	4.300
.1728	69.69	11.79	.333	.310
.1728	88.85	19.16	.445	.515
.1725	130.90	41.74	.653	1.022
.1729	165.70	66.57	.791	1.411
.1727	178.02	77.01	.837	1.715

Table (6). b = 0.593, D = 500 sec^{-1}, η = 200

H-in	Vo-ft/sec		I'	Wf/H
.0998	80.73	51.64	1.769	.9520
.0985	118.95	115.08	2.642	2.461
.0984	124.20	125.72	2.761	2.607
.0982	117.90	258.98	3.963	4.138
.0982	202.60	335.89	4.513	4.758
.0984	231.13	435.38	5.139	5.424
.0983	216.70	383.50	4.823	5.091

Table (7). b = 0.75, D = 500 sec^{-1}, 1 = 2.5H, η = 200.

H-in	Vo-ft/sec		I'	Wf/H
.0998	80.73	51.64	2.074	1.931
.0985	118.95	115.08	3.097	3.605
.0984	124.20	125.72	3.237	3.786
.0982	117.90	258.98	4.646	5.773
.0982	202.60	335.89	5.290	6.617
.0984	231.13	435.38	6.023	7.540

Table (8). b = 1.0, D = 500 sec^{-1}, 1 = 2.5H, η = 200.

$D\text{-}sec^{-1}$	H-in	Vo-ft/sec	Equation (11)or(16) Wf/H	Experimental Ref [2] Wf/H
500	0.643	134.08	3.698	3.542
450	"	"	3.504	"
400	"	"	3.437	"
350	"	"	3.356	"
300	"	"	3.255	"
250	"	"	3.128	"
200	"	"	2.96	"
150	"	"	2.728	"
100	"	"	2.376	"
75	"	"	2.113	"
60	"	"	1.896	"
40	"	"	1.393	"

Table (9). Influence of D on predictions based on equations (11) or (16). $1 = 2.5H$, $\eta = 200$.

1/H	Wf/H
1.0	3.432
2.0	3.996
3.0	4.254
4.0	4.401
5.0	4.497
6.0	4.565
7.0	4.615
8.0	4.654
9.0	4.685
10.0	4.710
11.0	4.770
12.0	4.789

Table (10). Influence of 1/H on predictions based on equations (11) or (16). b = .0593, η = 200, D = 470 sec^{-1}. H = .0643, = 417.16.

l_1 - in	H- in	Vo- ft/sec		Wf/H
0.1	.0643	134.08	323.055	3.325
0.2	"	"	"	3.698
0.3	"	"	"	3.852
0.4	"	"	"	3.935
0.5	"	"	"	3.988
0.6	"	"	"	4.025
0.8	"	"	"	4.071
1.0	"	"	"	4.100
0.1	.0644	152.60	417.16	3.807
0.2	"	"	"	4.273
0.3	"	"	"	4.469
0.5	"	"	"	4.646
0.7	"	"	"	4.728
1.0	"	"	"	4.793
0.1	.0638	180.06	591.78	4.534
0.2	"	"	"	5.150
0.3	"	"	"	5.416
0.5	"	"	"	5.662
0.1	.0638	165.06	497.30	4.173
0.2	"	"	"	4.707
0.3	"	"	"	4.935
0.5	"	"	"	5.142
0.7	"	"	"	5.239
1.0	"	"	"	5.316
0.1	.0647	233.0	963.55	5.594
0.2	"	"	"	6.499
0.3	"	"	"	6.912
0.5	"	"	"	7.303
0.7	"	"	"	7.492
1.0	"	"	"	7.644

Table (11).

(continued)

Table (11). Influence of hinge width on the predictions based on equations (11) and (16). $b = 0.593$, $D = 500 \sec^{-1}$, $\eta = 200$.

REFERENCES

1. Jones, N.; "A Theoretical Study of the Dynamic Plastic Behavior of Beams and Plates with Finite Deflections"; Int. J. Solids Structures, 1971, Vol. 7, pp. 1007-1029.

2. Jones, N., Uran, T.O., and Tekin, S.A.; "The Dynamic Plastic Behavior of Fully Clamped Rectangular Plates"; Int. J. Solids Structures, 1970, Vol. 6, pp. 1499-1512.

3. Cowper, G.R., and Symonds, P.S.; "Strain-Hardening and Strain-Rate Effects in the Impact Loading of Cantilever Beams"; Brown University Technical Report C11-28, September 1957.

4. Symonds, P.S., and Jones, N.; "Impulsive Loading of Fully Clamped Beams with Finite Plastic Deflections"; Brown University Technical Report II, August 1970.

5. Jones, N., and Baeder, R.A.; "An Experimental Study of the Dynamic Plastic Behavior of Rectangular Plates"; M.I.T. Ocean Engineering Report No. 72-1, January 1972.

6. Wood, R.H.; "Plastic and Elastic Design of Slabs and Plates"; Ronald Press, 1961.

7. Martin, J.B., and Symonds, P.S.; "Mode Approximations for Impulsively-Loaded Rigid-Plastic Structures"; Journal of the Engineering Mechanics Division, ASCE Vol. 92, No. EMS, Proc. Paper 4938, October 1966, pp. 43-66.

8. Symonds, P.S.; "Viscoplastic Behavior in Response of Structures to Dynamic Loading"; 'Behavior of Materials Under Dynamic Loading', edited by N.J. Huffington, pp. 106-124, ASME, 1965.

9. Perrone, N.; "On a Simplified Method for Solving Impulsively Loaded Structures of Rate-Sensitive Materials"; Journal of Applied Mechanics, Paper No. 65-APM-10, September 1965.

10. Perrone, N.; "Impulsively Loaded Strain Rate Sensitive Plates"; Journal of Applied Mechanics, Paper No. 67-APMF, June 1967.

11. Perzyna, P.; "The Constitutive Equation for Rate-Sensitive Plastic Materials", Quart. of Applied Mechanics, Vol. XX, No. 4, January 1963.

12. Malvern, L.E.; "The Propagation of Longitudinal Waves of Plastic Deformation in a Bar of Material Exhibiting a Strain-Rate Effect"; Journal of Applied Mechanics, Vol. 18, No. 82, 1951.

13. Marsh, K.J. and Campbell, J.D.; "The Effect of Strain Rate on the Post-Yield Flow of Mild Steel"; Journal Mech. Phys. Solids, Vol. 11, pp. 49-63, 1963.

14. Jones, N.; "Influence of Strain-Hardening and Strain-Rate Sensitivity on the Permanent Deformation of Impulsively Loaded Rigid-Plastic Beams"; Int. J. Mech. Sci., Vol. 9, pp. 777-796, 1967.

15. Martin, J.B.; "Impulsive Loading Theorems for Rigid-Plastic Continua"; Proc. ASCE, 90, pp. 27-42, 1964.

16. Bodner, S.R.; "Deformation of Rate-Sensitive Structures Under Impulsive Loading"; Engineering Plasticity, Cambridge University Press, 1968, Eds. J. Heyman and F.A. Leckie, pp. 77-92.

17. Bodner, S.R.; "Strain Rate Effects in Dynamic Loading of Structures" Behavior of Materials Under Dynamic Loading, Edited by N.J. Huffington, A.S.M.E., 1965.

18. Aspden, R.J., and Campbell, J.D.;"The Effect of Loading Rate on the Elasto-Plastic Flexure of Steel Beams"; Proc. of the Royal Society, A, Vol. 290, 1966.

APPENDIX A

COMPUTER PROGRAMME FOR TABLES

```
C     A PROGRAMME TO COMPUTE THE PERMANENT DEFORMATION OF VISCOPLASTIC RECTAN-  MARM0001
C      GULAR PLATE SUBJECTED TO A UNIFORMLY DISTRIBUTED DYNAMIC PRESSURE PULSE   MARM0002
C    B=SEMI-WIDTH OF PLATE,L=SEMI-LENGTH OF PLATE,H=PLATE THICKNESS,L1=PLASTIC  MARM0003
C    HINGE WIDTH,DOVERH=PERM. DEFLECTION OVER THICKNESS IF W .LE. 1.0,WOVERH=   MARM0004
C    PERM. DEFLECTION OVER H IF W .GE. 1   ,VZERO= INITIAL VELOCITY,PCOL=STATIC MARM0005
C    COLLAPSE PRESSURE,MZERO=STATIC LIMITING MOMENT PER UNIT LENGTH OF PLATE    MARM0006
C    MU=MASS PER UNIT AREA OF PLATE,DENS=MATERIAL DENSITY,PZERO=APPLIED PRESSUR MARM0007
C   E),LAMDA=A NONDIMENSIONAL IMPULSE PARAMETER,IMPULS=A NONDIMENSIONAL PARAMET MARM0008
C    ER,RHO AND RHO2 ARE NONDIMESIONAL TIMES.-                                  MARM0009
      REAL L,L1,MZERO,IPRIME,IM,IMPULS,LAMDA,MU                                 MARM0010
      REAL COEFS(4),PROOTS(4),CROOTS(4),POLY(5)                                 MARM0011
      REAL GOEFS(5),FROOTS(5),GROOTS(5)                                         MARM0012
      REAL COEF(3),TAUF(3),CTAUF(3)                                             MARM0013
      DATA REL/1.0E-2/,LIMIT/50/                                                MARM0014
    1 READ(5,100)B,L,L1,H,DENS,VZERO,SIGMAC,P,D                                 MARM0015
  100 FORMAT(6F10.5,F10.4,F5.2,F5.1)                                            MARM0016
  201 FORMAT(/5X,'DOVERH=',F22.12)                                              MARM0017
  203 FORMAT(///5X,'WOVERH=',F20.9)                                             MARM0018
  204 FORMAT(//4X,'IPRIME=',F10.5)                                              MARM0019
  205 FORMAT(/5X,'IMPULS=',F10.5)                                               MARM0020
  206 FORMAT(5X,'PZERO=',F20.7)                                                 MARM0021
  207 FORMAT(//5X,'B=',F10.5,5X,'L=',F10.5,'L1=',F10.5,5X,'H=',F10.5,           MARM0022
     1/5X,'DENS=',F10.5,5X,'VZERO=',F10.5,5X,'SIGMAC=',F10.4,5X,'P=',           MARM0023
     1 F5.2,4X,'D=',F5.1)                                                       MARM0024
  208 FORMAT(///5X,'NEGATIVE TIME;NO THIRD STAGE')                              MARM0025
  209 FORMAT(5X,'LAMDA=',F10.5)                                                 MARM0026
  210 FORMAT(5X,'TAUS=',E20.5)                                                  MARM0027
  216 FORMAT(5X,'HTA=',F8.2)                                                    MARM0028
  217 FORMAT(5X,'PCOL=',F10.3)                                                  MARM0029
  220 FORMAT(//'0','IERROR=',I2,5X,'NROOTS=',I2)                                MARM0030
  125 FORMAT('0','ALL ROOTS FOUND ARE NEGATIVE')                                MARM0031
  227 FORMAT(//'0','IERROR=',I2,5X,'NROOTS=',I2)                                MARM0032
  232 FORMAT(//5X,'ALL ROOTS FOUND NEGATIVE')                                   MARM0033
      WRITE(6,207) B,L,L1,H,DENS,VZERO,SIGMAC,P,D                               MARM0034
      L=L/2.                                                                    MARM0035
      B=B/2.                                                                    MARM0036
```
PAGE 1

```
      MZERO=SIGMAC*H*H/4.                                               MARM0037
      BETA=B/L                                                          MARM0038
      TANPHI=SQRT(3+BETA*BETA)-BETA                                     MARM0039
      XO=BETA*TANPHI                                                    MARM0040
      PHI=ATAN(TANPHI)                                                  MARM0041
      MU=(DENS*H)/(32.17*12.)                                           MARM0042
      PCOL=((12.*MZERO/B**2)*(1.+BETA/TANPHI))/(3.-BETA*TANPHI)         MARM0043
      WRITE(6,217) PCOL                                                 MARM0044
  225 HTA=200.                                                          MARM0045
 5003 WRITE(6,216) HTA                                                  MARM0046
  226 PZERO=HTA*PCOL                                                    MARM0047
      WRITE(6,206) PZERO                                                MARM0048
      TAUS=(MU*VZERO*12.)/PZERO                                         MARM0049
      WRITE(6,210) TAUS                                                 MARM0050
      LAMDA=MU*VZERO**2*144.*L**2/(MZERO*H)                             MARM0051
      WRITE(6,209) LAMDA                                                MARM0052
      IM=TAUS*PZERO                                                     MARM0053
      IPRIME=IM/SQRT(MU*H*PCOL)                                         MARM0054
      IMPULS=LAMDA*(IM/(MU*VZERO*12.))**2                               MARM0055
      WRITE(6,204) IPRIME                                               MARM0056
      WRITE(6,205) IMPULS                                               MARM0057
 5201 C2=(2.*P/((2.*P)+1))*((H/(2.*B*L1*D))**(1/P))                     MARM0058
     C3=(2.*P/((2.*P)+1.))*(H/(2.*B*L1*D*TANPHI))**(1./P)               MARM0059
      C1=(2.*P/((2.*P)+1.))*(H/(4.*B*L1*D*SIN(PHI)))**(1./P)            MARM0060
      A1=(C2*L/B)-(C2*SIN(PHI)**2+C1+C3*COS(PHI)**2)/(2.*SIN(PHI)*COS(PHI))  MARM0061
     1 HI))                                                             MARM0062
      A2=3*C2*L/B-3*C2*TANPHI+(3*C1-C2*SIN(PHI)**2-C3*COS(PHI)**2)/     MARM0063
     1 (2.*SIN(PHI)*COS(PHI))                                           MARM0064
      B1=((MU*B*B)/(12.*MZERO))*((2.-BETA*TANPHI)/(1.+BETA/TANPHI))     MARM0065
      B2=(1.+2.*(1.-BETA*TANPHI)/(1.+BETA/TANPHI))/(3.*H*H)             MARM0066
      B3=PZERO/PCOL                                                     MARM0067
      B4=(A1*BETA)/(1.+BETA/TANPHI)                                     MARM0068
      B5=(A2*BETA)/((1.+BETA/TANPHI)*H*H*3.)                            MARM0069
      H1=B5/B1                                                          MARM0070
      H2=B4/B1                                                          MARM0071
      H3=B2/B1                                                          MARM0072
                                                                 PAGE    2
```

```
      D1=(B3-1.)/B1
      D2=(-1.)/B1
      DEFL1=((D1*TAUS*TAUS)/2.)*(1.-(H2*TAUS/3.)+(((H2*TAUS)**2)/12.)
     1 -(((H2*TAUS)**3)/60.)+(((H2*TAUS)**4)/360.)-((D1*H3)*TAUS**4)/60.)
     1 +(H3*D1*(TAUS**5)/420.)-((H2**4)*(TAUS**5)/2520.)+((H2*H3*D1)
     1 *(TAUS**5)/126.)-((H1*D1*D1)*(TAUS**5)/84.))
      DDEFL1=D1*TAUS*(1.-H2*TAUS/2.+H2**2*TAUS**2/6.-H2**3*TAUS**3/24.
     1 +H2**4*TAUS**4/120.-H3*D1*TAUS**4/20.+H3*D1*TAUS**5/120.
     1  -H2**4*TAUS**5/720.+H2*H3*D1*TAUS**5/36.-H1*D1*D1*TAUS**5/24.)
      PAR=H2+H1*DEFL1*DEFL1
      TERM2=D2/2.-(PAR*DDEFL1+H3*DEFL1**2)/2.
      TERM3=(TERM2*PAR+DEFL1*DDEFL1*(H3+H1*DDEFL1))/(-3.)
      TERM4=(2.*TERM2*DEFL1*(3.*H1*DDEFL1+H3)+3.*TERM3*PAR+DDEFL1**2*(H
     1 1*DDEFL1+H3))/(-1.)
      AA2=2.*TERM2*TAUS
      AA3=3.*TERM3*TAUS*TAUS
      AA4=4.*TERM4*TAUS*TAUS*TAUS
      NCOEFS=4
      COEFS(1)=DDEFL1
      COEFS(2)=AA2
      COEFS(3)=AA3
      COEFS(4)=AA4
      CALL ALLOW(6,6,6)
      CALL PRBM(COEFS,NCOEFS,RROOTS,CROOTS,POLY,NROOTS,IERROR,REL,
     1 LIMIT,DEVN)
      WRITE(6,220) IERROR,NROOTS
      IF(NROOTS .EQ. 0) GO TO 1
      IF (IERROR .NE. 0) GO TO 1
      CALL SORT1(1,3,LL,RROOTS)
      IF(LL .EQ. 0) GO TO 3001
      GO TO 3002
 3001 WRITE(6,125)
      GO TO 1
 3002 CONTINUE
      RHOT=RROOTS(LL)
 44   DOVERH=(DEFL1+DDEFL1*TAUS*RHOT+TERM2*TAUS**2*RHOT**2+TERM3*TAUS**
```

```
     1 3*RHOT**3+TERM4*TAUS**4*RHOT**4)/H                                    MARM0109
451    WRITE(6,201) DOVERH                                                   MARM0110
       IF(DOVERH .LT. 1.) GO TO 1001                                         MARM0111
45     PI1=MU*(2.-XO)/((3.-XO)*PCOL)                                         MARM0112
       PI2=2.*(3.-3.*XO+XO**2)/((3.-XO)*H)                                   MARM0113
       PI3=(H*BETA/3.)*(1/TANPHI+TANPHI)/(1+BETA/TANPHI)                     MARM0114
       PI4=(C2/(H*(1.+BETA/TANPHI)))*(2.-2.*XO+XO/((2.*SIN(PHI))**(1./P)     MARM0115
     1 *SIN(PHI)**2))                                                        MARM0116
       PI5=(C2*BETA*H/(3.+3.*BETA/TANPHI))* (1./(TANPHI**(1.+1./P))+TANPHI)  MARM0117
     1 HI)                                                                   MARM0118
       Z1=PI2/PI1                                                            MARM0119
       Z2=PI3/PI1                                                            MARM0120
       Z3=PI4/PI1                                                            MARM0121
       Z4=PI5/PI1                                                            MARM0122
       AAA2=TERM2*TAUS**2                                                    MARM0123
       AAA3=TERM3*TAUS**3                                                    MARM0124
       AAA4=TERM4*TAUS**4                                                    MARM0125
       NCOEFS=5                                                              MARM0126
       GOEFS(1)=(DEFL1-H)                                                    MARM0127
       GOEFS(2)=DDEFL1*TAUS                                                  MARM0128
       GOEFS(3)=AAA2                                                         MARM0129
       GOEFS(4)=AAA3                                                         MARM0130
       GOEFS(5)=AAA4                                                         MARM0131
       CALL ALLOW(7,7,7)                                                     MARM0132
       CALL PRBM(GOEFS,NCOEFS,FROOTS,GROOTS,POLY,NROOTS,IERROR,              MARM0133
     1 REL,LIMIT,DEVN)                                                       MARM0134
       WRITE(6,227) IERROR,NROOTS                                            MARM0135
       IF (NROOTS .EQ. 0) GO TO 1                                            MARM0136
       IF (IERROR .NE. 0) GO TO 1                                            MARM0137
       CALL SORT1(1,4,LLL,FROOTS)                                            MARM0138
       IF (LLL .EQ. 0) GO TO 3011                                            MARM0139
       GO TO 3012                                                            MARM0140
3011   WRITE(6,232)                                                          MARM0141
       GO TO 1                                                               MARM0142
3012   CONTINUE                                                              MARM0143
       RHOT2=FROOTS(LLL)                                                     MARM0144
```

```
      DDEFL2=DDEFL1+2.*TERM2*TAUS*RHOT2+3.*TERM3*(TAUS*RHOT2)**2+
     1 4.*TERM4*(TAUS*RHOT2)**3
      ALPHA2=-(Z1*H+Z2/H+(Z4+Z3*H**2)*DDEFL2/H)/2.
      ALPHA3=-(Z1*H*DDEFL2+Z3*H*DDEFL2**2+ALPHA2*(DDEFL2+Z4+Z3*H*H))/
     1 (3.*H)
      NCOEF=3
      COEF(1)=DDEFL2
      COEF(2)=2.*ALPHA2
      COEF(3)=3.*ALPHA3
      CALL ALLOW (6,6,6)
      CALL PRBM (COEF,NCOEF,TAUF,CTAUF,POLY,NROOTS,IERROR,REL,LIMIT,
     1 DEVN)
      WRITE(6,227) IERROR,NROOTS
      IF (NROOTS .EQ. 0) GO TO 1
      IF (IERROR .NE. 0) GO TO 1
      CALL SORT4 (1,2,KK,TAUF)
      IF (KK .EQ. 0)GO TO 3021
      GO TO 3022
 3021 WRITE(6,208)
      GO TO 1
 3022 CONTINUE
      TAUC=TAUF(KK)
 555  WOVERH=1.+DDEFL2*TAUC/H+ALPHA2*TAUC**2/H+ALPHA3*TAUC**3/H
      WRITE(6,203) WOVERH
 1001 IF(HTA .EQ. 100.0) GO TO 225
      GO TO 1
 1000 CONTINUE
      STOP
      END
```

```
      SUBROUTINE SORT1(M,N,L,A)
      DIMENSION  A(4)
      K=0
      GO TO 1
      ENTRY SORT2(N)
      M=1
      K=1
      GO TO 1
      ENTRY SORT3(M,N)
      K=2
1     NM1=N-1
      DO 60 I=1,NM1
      JJ=N-I
      DO 50 J=1,JJ
      IF (K .EQ. 2 .AND. ABS(A(J)) .GT. ABS(A(J+1)) .OR. K .NE. 2 .AND.
     1 A(J) .GT. A(J+1)) GO TO 10
      GO TO 50
10    T=A(J)
      A(J)=A(J+1)
      A(J+1)=T
50    CONTINUE
60    CONTINUE
      IF (K .NE. 0) RETURN
      ENTRY FIRSTP(N,M,L)
      L=0
      DO 40 I=M,N
      IF (A(I) .GE. 0.) GO TO 20
40    CONTINUE
      RETURN
20    L=I
      RETURN
      END
```

PAGE 6

```
      SUBROUTINE SORT4(M,N,L,A)
      DIMENSION A(2)
      K=0
      GO TO 1
      ENTRY SORT5
      M=1
      K=1
      GO TO 1
      ENTRY SORT6(M,N)
      K=2
 1    NM1=N-1
      DO 60 I=1,NM1
      JJ=N-I
      DO 50 J=1,JJ
      IF (K .EQ. 2 .AND. ABS(A(J)) .GT. ABS(A(J+1)) .OR. K .NE. 2 .AND.
     1 A(J) .GT. A(J+1)) GO TO 10
      GO TO 50
 10   T=A(J)
      A(J)=A(J+1)
      A(J+1)=T
 50   CONTINUE
 60   CONTINUE
      IF (K .NE. 0) RETURN
      ENTRY FIRST(N,M,L)
      L=0
      DO 40 I=M,N
      IF (A(I) .GE. 0.) GO TO 20
 40   CONTINUE
      RETURN
 20   L=I
      RETURN
      END
```

3.0	5.0625	0.15	.0643	.279	134.08	35900.0	1.0	470.	DATA0001
3.0	5.0625	0.15	.0644	.279	152.60	35900.0	1.0	470.0	DATA0002
3.0	5.0625	0.159	.0638	.279	165.06	35900.0	1.0	470.	DATA0003
3.0	5.0625	0.159	.0638	.279	180.06	35900.0	1.0	470.	DATA0004
3.0	5.0625	0.152	.0647	.279	233.00	35900.0	1.0	470.	DATA0005
3.0	5.0625	0.158	0.0635	.279	234.08	35900.0	1.0	470.	DATA0006
3.0	5.0625	0.247	0.0998	.279	80.73	33800.0	1.0	470.	DATA0007
3.0	5.0625	0.2462	0.0985	.279	118.95	33800.0	1.0	470.	DATA0008
3.0	5.0625	0.246	0.0984	.279	124.20	33800.0	1.0	470.	DATA0009
3.0	5.0625	0.2459	0.0982	.279	177.90	33800.0	1.0	470.	DATA0010
3.0	5.0625	0.2459	0.0982	.279	202.60	33800.0	1.0	470.	DATA0011
3.0	5.0625	0.246	.0983	.279	216.70	33800.0	1.0	470.0	DATA0012
3.0	5.0625	0.2461	0.0984	.279	231.13	33800.0	1.0	470.0	DATA0013
3.0	5.0625	0.432	.1728	.279	69.69	36800.0	1.0	470.0	DATA0014
3.0	5.0625	0.432	.1728	.279	88.85	36800.0	1.0	470.	DATA0015
3.0	5.0625	0.43	0.1725	.279	130.90	36800.0	1.0	470.	DATA0016
3.0	5.0625	0.4321	0.1729	.279	165.70	36800.0	1.0	470.	DATA0017
3.0	5.0625	0.4319	0.1727	.279	178.02	36800.0	1.0	470.	DATA0018
3.0	5.0625	0.25	0.0998	.279	80.73	33800.0	1.0	460.	DATA0019
3.0	5.0625	0.25	0.0985	.279	118.95	33800.0	1.0	460.	DATA0020
3.0	5.0625	0.23	0.0984	.279	124.20	33800.0	1.0	460.	DATA0021
3.0	5.0625	0.25	0.0982	.279	177.90	33800.0	1.0	460.0	DATA0022
3.0	5.0625	0.25	0.0982	.279	202.60	33800.0	1.0	460.	DATA0023
3.0	5.0625	0.25	.0983	.279	216.70	33800.0	1.0	460.0	DATA0024
3.0	5.0625	0.25	0.0984	.279	231.13	33800.0	1.0	460.	DATA0025
3.0	5.0625	0.3	.1728	.279	69.69	36800.0	1.0	460.0	DATA0026
3.0	5.0625	0.3	.1728	.279	88.85	36800.0	1.0	460.	DATA0027
3.0	5.0625	0.3	0.1725	.279	130.90	36800.0	1.0	460.	DATA0028
3.0	5.0625	0.30	0.1729	.279	165.70	36800.0	1.0	460.	DATA0029
3.0	5.0625	0.30	0.1727	.279	178.02	36800.0	1.0	460.	DATA0030
3.0	5.0625	0.15	.0643	.279	134.08	35900.0	1.0	460.	DATA0031
3.0	5.0625	0.15	.0644	.279	152.60	35900.0	1.0	460.	DATA0032
3.0	5.0625	0.15	.0638	.279	165.06	35900.0	1.0	460.	DATA0033
3.0	5.0625	0.15	.0638	.279	180.06	35900.0	1.0	460.	DATA0034
3.0	5.0625	0.15	.0647	.279	233.00	35900.0	1.0	460.	DATA0035
3.0	5.0625	0.15	0.0635	.279	234.08	35900.0	1.0	460.	DATA0036

3.0	5.0625	0.15	.0643	.279	134.08	35900.0	1.0	400.	DATA0037
3.0	5.0625	0.15	.0643	.279	134.08	35900.0	1.0	350.	DATA0038
3.0	5.0625	0.15	.0643	.279	134.08	35900.0	1.0	300.0	DATA0039
3.0	5.0625	0.15	.0643	.279	134.08	35900.0	1.0	250.	DATA0040
3.0	5.0625	0.15	.0643	.279	134.08	35900.0	1.0	200.	DATA0041
3.0	5.0625	0.15	.0643	.279	134.08	35900.0	1.0	150.	DATA0042
3.0	5.0625	0.15	.0643	.279	134.08	35900.0	1.0	100.	DATA0043
3.0	5.0625	0.15	.0643	.279	134.08	35900.0	1.0	75.	DATA0044
3.0	5.0625	0.15	.0643	.279	134.08	35900.0	1.0	60.	DATA0045
3.0	5.0625	0.15	.0643	.279	134.08	35900.0	1.0	40.2	DATA0046
1.250	5.	0.3	.1728	.279	69.69	36800.0	1.0	500.	DATA0047
1.250	5.	0.3	.1728	.279	88.85	36800.0	1.0	500.	DATA0048
1.250	5.	0.3	.1728	.279	153.36	36800.0	1.0	500.	DATA0049
1.250	5.	0.3	.1729	.279	165.70	36800.0	1.0	500.	DATA0050
1.250	5.	0.3	.1728	.279	166.26	36800.0	1.0	500.	DATA0051
1.250	5.	0.3	.1727	.279	178.02	36800.0	1.0	500.	DATA0052
0.625	2.511	0.25	.106	.279	391.6	36400.	1.0	500.	DATA0053
0.625	2.511	0.25	.106	.279	257.75	36400.	1.0	500.	DATA0054
3.7970	5.0625	0.25	0.0998	.279	80.73	33800.0	1.0	500.	DATA0055
3.7970	5.0625	0.25	0.0985	.279	118.95	33800.0	1.0	500.	DATA0056
3.7970	5.0625	0.23	0.0984	.279	124.20	33800.0	1.0	500.	DATA0057
3.7970	5.0625	0.25	0.0982	.279	177.90	33800.0	1.0	500.	DATA0058
3.797	5.0625	0.25	0.0982	.279	202.60	33800.0	1.0	500.	DATA0059
3.797	5.0625	0.25	0.0984	.279	231.13	33800.0	1.0	500.	DATA0060
3.7970	5.0625	0.25	.0993	.279	216.70	33800.0	1.0	500.0	DATA0061
5.0625	5.0625	0.25	0.0998	.279	80.73	33800.0	1.0	500.	DATA0062
5.0625	5.0625	0.25	0.0985	.279	118.95	33800.0	1.0	500.	DATA0063
5.0625	5.0625	0.23	0.0984	.279	124.20	33800.0	1.0	500.	DATA0064
5.0625	5.0625	0.25	0.0982	.279	177.90	33800.0	1.0	500.	DATA0065
5.0625	5.0625	0.25	0.0982	.279	202.60	33800.0	1.0	500.	DATA0066
5.0625	5.0625	0.25	0.0984	.279	231.13	33800.0	1.0	500.	DATA0067
5.0625	5.0625	0.3	.1728	.279	166.26	36800.0	1.0	500.0	DATA0068
5.0625	5.0625	0.3	.1728	.279	88.85	36800.0	1.0	500.	DATA0069
5.0625	5.0625	0.3	.1728	.279	69.69	36800.0	1.0	500.0	DATA0070
5.0625	5.0625	0.3	.1731	.279	171.16	36800.0	1.0	500.0	DATA0071
5.0625	5.0625	0.3	.1727	.279	178.02	36800.0	1.0	500.0	DATA0072

PAGE 9

3.0	60.00	0.25	0.0998	.279	80.73	33800.0	1.0	40.	DATA0073
3.	60.00	0.25	0.0985	.279	118.95	33800.0	1.0	40.	DATA0074
3.000	60.0000	0.23	0.0984	.279	124.20	33800.0	1.0	40.0	DATA0075
3.00	60.0000	0.25	0.0982	.279	177.90	33800.0	1.0	40.	DATA0076
3.00	60.0000	0.25	0.0982	.279	202.60	33800.0	1.0	40.	DATA0077
3.00	60.0000	0.25	0.0984	.279	231.13	33800.0	1.0	40.	DATA0078
3.0	5.0625	0.1	.0643	.279	134.08	35900.0	1.0	500.	DATA0079
3.0	5.0625	0.2	.0643	.279	134.08	35900.0	1.0	500.	DATA0080
3.0	5.0625	0.3	.0643	.279	134.08	35900.0	1.0	500.	DATA0081
3.0	5.0625	0.5	.0643	.279	134.08	35900.0	1.0	500.	DATA0082
3.0	5.0625	0.7	.0643	.279	134.08	35900.0	1.0	500.	DATA0083
3.0	5.0625	1.0	.0643	.279	134.08	35900.0	1.0	500.	DATA0084
3.0	5.0625	0.1	.0644	.279	152.60	35900.0	1.0	500.	DATA0085
3.0	5.0625	0.2	.0644	.279	152.60	35900.0	1.0	500.	DATA0086
3.0	5.0625	0.3	.0644	.279	152.60	35900.0	1.0	500.	DATA0087
3.0	5.0625	0.5	.0644	.279	152.60	35900.0	1.0	500.	DATA0088
3.0	5.0625	0.7	.0644	.279	152.60	35900.0	1.0	500.	DATA0089
3.0	5.0625	1.0	.0644	.279	152.60	35900.0	1.0	500.	DATA0090
3.0	5.0625	0.1	.0638	.279	180.06	35900.0	1.0	500.	DATA0091
3.0	5.0625	0.2	.0638	.279	180.06	35900.0	1.0	500.	DATA0092
3.0	5.0625	0.3	.0638	.279	180.06	35900.0	1.0	500.	DATA0093
3.0	5.0625	0.5	.0638	.279	180.06	35900.0	1.0	500.	DATA0094
3.0	5.0625	0.7	.0638	.279	180.06	35900.0	1.0	500.	DATA0095
3.0	5.0625	1.0	.0638	.279	180.06	35900.0	1.0	500.	DATA0096
3.0	5.0625	0.1	.0638	.279	165.06	35900.0	1.0	500.	DATA0097
3.0	5.0625	0.2	.0638	.279	165.06	35900.0	1.0	500.	DATA0098
3.0	5.0625	0.3	.0638	.279	165.06	35900.0	1.0	500.	DATA0099
3.0	5.0625	0.5	.0638	.279	165.06	35900.0	1.0	500.	DATA0100
3.0	5.0625	0.7	.0638	.279	165.06	35900.0	1.0	500.	DATA0101
3.0	5.0625	1.0	.0638	.279	165.06	35900.0	1.0	500.	DATA0102
3.0	5.0625	0.1	.0647	.279	233.00	35900.0	1.0	500.	DATA0103
3.0	5.0625	0.2	.0647	.279	233.00	35900.0	1.0	500.	DATA0104
3.0	5.0625	0.3	.0647	.279	233.00	35900.0	1.0	500.	DATA0105
3.0	5.0625	0.5	.0647	.279	233.00	35900.0	1.0	500.	DATA0106
3.0	5.0625	0.7	.0647	.279	233.00	35900.0	1.0	500.	DATA0107
3.0	5.0625	1.0	.0647	.279	233.00	35900.0	1.0	500.	DATA0108

PAGE 10

3.0	5.0625	0.1	0.0635	.279	234.08	35900.0	1.0	500.	DATA0109
3.0	5.0625	0.2	0.0635	.279	234.08	35900.0	1.0	500.	DATA0110
3.0	5.0625	0.3	0.0635	.279	234.08	35900.0	1.0	500.	DATA0111
3.0	5.0625	0.5	0.0635	.279	234.08	35900.0	1.0	500.	DATA0112
3.0	5.0625	0.7	0.0635	.279	234.08	35900.0	1.0	500.	DATA0113
3.0	5.0625	1.0	0.0635	.279	234.08	35900.0	1.0	500.	DATA0114
3.0	5.0625	0.25	0.0998	.279	80.73	33800.0	1.0	500.0	DATA0115
3.0	5.0625	0.25	0.0985	.279	118.95	33800.0	1.0	500.	DATA0116
3.0	5.0625	0.23	0.0984	.279	124.20	33800.0	1.0	500.	DATA0117
3.0	5.0625	0.25	0.0982	.279	177.90	33800.0	1.0	500.	DATA0118
3.0	5.0625	0.25	0.0982	.279	202.60	33800.0	1.0	500.	DATA0119
3.0	5.0625	0.25	.0983	.279	216.70	33800.0	1.0	500.0	DATA0120
3.0	5.0625	0.25	0.0984	.279	231.13	33800.0	1.0	500.	DATA0121
3.0	5.0625	0.3	.1728	.279	69.69	36800.0	1.0	500.0	DATA0122
3.0	5.0625	0.3	.1728	.279	88.85	36800.0	1.0	500.	DATA0123
3.0	5.0625	0.3	0.1725	.279	130.90	36800.0	1.0	500.	DATA0124
3.0	5.0625	0.30	0.1729	.279	165.70	36800.0	1.0	500.	DATA0125
3.0	5.0625	0.30	0.1727	.279	178.02	36800.0	1.0	500.	DATA0126
									DATA0127

APPENDIX B

COMPUTER PROGRAMME FOR GRAPHS

```
C   A PROGRAMME FOR PLOTTING DEFLECTION-THICKNESS RATIO VS. IPRIME
C   FOR DIFFERENT VALUES OF HTA (SEE PREVIOUS PROGRAMME MARM)
C       B=SEMI-WIDTH OF PLATE,L=SEMI-LENGTH OF PLATE,H=PLATE THICKNESS,L1=PLASTIC
C       HINGE WIDTH,DOVERH=PERM. DEFLECTION OVER THICKNESS IF W .LE. 1.0,WOVERH=
C       PERM. DEFLECTION OVER H IF W .GE. 1   ,VZERO= INITIAL VELOCITY,PCOL=STATIC
C       COLLAPSE PRESSURE,MZERO=STATIC LIMITING MOMENT PER UNIT LENGTH OF PLATE
C       MU=MASS PER UNIT AREA OF PLATE,DENS=MATERIAL DENSITY,PZERO=APPLIED PRESSUR
C      E),LAMDA=A NONDIMENSIONAL IMPULSE PARAMETER,IMPULS=A NONDIMENSIONAL PARAMET
C       ER,PHI AND PHI2 ARE NONDIMESIONAL TIMES.-
        REAL*4 L,L1,MZERO,IPRIME,IMPULS,LAMDA,MU
        DIMENSION COEFS(4),RROOTS(4),CROOTS(4),POLY(4),
     1 GOEFS(5),FROOTS(5),POL(5),GROOTS(5),COEF(3),TAUF(3),CTAUF(3),
     1 FOLY(3)
        DIMENSION YVER(4,18),XOR(18),TIT1(9),TIT2(9),TIT3(9),HTA(4),
     1 YV(18)
        DATA TIT1/'        ASPECT RATIO=.593            '/
        DATA TIT2/'                   IPRIME            '/
        DATA TIT3/'        DEFLECTION OVER THICKNESS    '/
        DO 7000  I=1,4
 7000   YVER(I,1)=0.
        CALL STOIDV('M9706-S246',9,3)
        HTA(1)=44.
        HTA(2)=100.
        HTA(3)=200.
        HTA(4)=300.
        XOR(1)=0.
        DO 1000  ISTAV=2,18
  1     READ(5,100)B,L,L1,H,DENS,VZERO,SIGMAC,P,D
 100    FORMAT(6F10.5,F10.4,F5.2,F5.1)
 201    FORMAT(/5X,'DOVERH=',F22.12)
 203    FORMAT(///5X,'WOVERH=',F20.9)
 204    FORMAT(//4X,'IPRIME=',F10.5)
 205    FORMAT(/5X,'IMPULS=',F10.6)
 206    FORMAT(5X,'PZERO=',F20.7)
 207   FORMAT(//5X,'B=',F10.5,5X,'L=',F10.5,'L1=',F10.5,5X,'H=',F10.5,
     1/5X,'DENS=',F10.5,5X,'VZERO=',F10.5,5X,'SIGMAC=',F10.4,5X,'P=',
```

```
    1 F5.2,4X,'D=',F5.1)                                            MAIN0037
  208   FORMAT(///5X,'NEGATIVE TIME:NO THIRD STAGE')                MAIN0038
  209   FORMAT(5X,'LAMDA=',F10.5)                                   MAIN0039
  210   FORMAT(5X,'TAUS=',F20.5)                                    MAIN0040
  216   FORMAT(5X,'HTA=',F8.2)                                      MAIN0041
  217   FORMAT(5X,'PCOL=',F10.3)                                    MAIN0042
  220   FORMAT(//'0','IERROR=',I2,5X,'NROOTS=',I2)                  MAIN0043
  125   FORMAT('0','ALL ROOTS FOUND ARE NEGATIVE')                  MAIN0044
  227   FORMAT(//'0','IERROR=',I2,5X,'NROOTS=',I2)                  MAIN0045
  232   FORMAT(//5X,'ALL ROOTS FOUND NEGATIVE')                     MAIN0046
  241   FORMAT(//,' YV VALUES',/,(6G20.6))                          MAIN0047
  240   FORMAT(//' XOR VALUES',/,(6G20.6))                          MAIN0048
        WRITE(6,207) B,L,L1,H,DENS,VZERO,SIGMAC,P,D                 MAIN0049
        L=L/2.                                                      MAIN0050
        B=B/2.                                                      MAIN0051
        MZERO=SIGMAC*H*H/4.                                         MAIN0052
        BETA=B/L                                                    MAIN0053
        TANPHI=SQRT(3+BETA*BETA)-BETA                               MAIN0054
        XO=BETA*TANPHI                                              MAIN0055
        PHI=ATAN(TANPHI)                                            MAIN0056
        MU=(DENS*H)/(32.17*12.)                                     MAIN0057
        PCOL=((12.*MZERO/B**2)*(1.+BETA/TANPHI))/(3.-BETA*TANPHI)   MAIN0058
        WRITE(6,217) PCOL                                           MAIN0059
        IPRIME=12.*MU*VZERO/SQRT(MU*H*PCOL)                         MAIN0060
        XOR(ISTAV)=IPRIME                                           MAIN0061
        DO 1003 JSTAV=1,4                                           MAIN0062
 5003   WRITE(6,216) HTA                                            MAIN0063
        PZERO=HTA(JSTAV)*PCOL                                       MAIN0064
        WRITE(6,206) PZERO                                          MAIN0065
        TAUS=(MU*VZERO*12.)/PZERO                                   MAIN0066
        WRITE(6,210) TAUS                                           MAIN0067
        LAMDA=MU*VZERO**2*144.*L**2/(MZERO*H)                       MAIN0068
        WRITE(6,209) LAMDA                                          MAIN0069
        IMPULS=LAMDA*(IM/(MU*VZERO*12.))**2                         MAIN0070
        WRITE(6,204) IPRIME                                         MAIN0071
        WRITE(6,205) IMPULS                                         MAIN0072
                                                               PAGE   2
```

```
 201 C2=(2.*P/((2.*P)+1))*((H/(2.*B*L1*D))**(1/P))
     C3=(2.*P/((2.*P)+1.))*(H/(2.*B*L1*D*TANPHI))**(1./P)
     C1=(2.*P/((2.*P)+1.))*(H/(4.*B*L1*D*SIN(PHI)))**(1./P)
     A1=(C3*L/3)-(C2*SIN(PHI)**2+C1+C3*COS(PHI)**2)/(2.*SIN(PHI)*COS(PHI))
    1 HI))
     A2=3*C2*L/B-3*C2*TANPHI+(3*C1-C2*SIN(PHI)**2-C3*COS(PHI)**2)/
    1 (2.*SIN(PHI)*COS(PHI))
     B1=((MU*P*B)/(12.*MZERO))*((2.-BETA*TANPHI)/(1.+BETA/TANPHI))
     B2=(1.+2.*(1.-BETA*TANPHI)/(1.+BETA/TANPHI))/(3.*H*H)
     B3=PZERO/PCCL
     B4=(A1*BETA)/(1.+BETA/TANPHI)
     B5=(A2*BETA)/((1.+BETA/TANPHI)*H*H*3.)
     H1=B5/B1
     H2=B4/B1
     H3=B2/B1
     D1=(B3-1.)/B1
     D2=(-1.)/B1
     DEFL1=((D1*TAUS*TAUS)/2.)*(1.-(H2*TAUS/3.)+(((H2*TAUS)**2)/12.)
    1 -(((H2*TAUS)**3)/60.)+(((H2*TAUS)**4)/360.)-((D1*H3)*TAUS**4)/60.)
    1 +(H3*D1*(TAUS**5)/420.)-((H2**4)*(TAUS**5)/2520.)+((H2*H3*D1)
    1 *(TAUS**5)/126.)-((H1*D1*D1)*(TAUS**5)/84.))
     DDEFL1=D1*TAUS*(1.-H2*TAUS/2.+H2**2*TAUS**2/6.-H2**3*TAUS**3/24.
    1 +H2**4*TAUS**4/120.-H3*D1*TAUS**4/20.+H3*D1*TAUS**5/120.
    1  -H2**4*TAUS**5/720.+H2*H3*D1*TAUS**5/36.-H1*D1*D1*TAUS**5/24.)
     PAR=H2+H1*DEFL1*DEFL1
     TERM2=D2/2.-(PAR*DDEFL1+H3*DEFL1**2)/2.
     TERM3=(TERM2*PAR+DEFL1*DDEFL1*(H3+H1*DDEFL1))/(-3.)
     TERM4=(2.*TERM2*DEFL1*(3.*H1*DDEFL1+H3)+3.*TERM3*PAR+DDEFL1**2*(H
    1 1*DDEFL1+H3))/(-1.)
     AA2=2.*TERM2*TAUS
     AA3=3.*TERM3*TAUS*TAUS
     AA4=4.*TERM4*TAUS*TAUS*TAUS
     NCOEFS=4
     COEFS(1)=DDEFL1
     COEFS(2)=AA2
     COEFS(3)=AA3
```

```
      COEFS(4)=AA4                                                      MAIN0109
      CALL PRBM(COEFS,NCOEFS,RROOTS,CROOTS,POLY,NROOTS,IERROR)          MAIN0110
      WRITE(6,220) IERROR,NROOTS                                        MAIN0111
      IF(NROOTS .EQ. 0) GO TO 1                                         MAIN0112
      IF (IERROR .NE. 0) GO TO 1                                        MAIN0113
      CALL SORT1(1,3,LL,RROOTS)                                         MAIN0114
      IF(LL .EQ. 0) GO TO 3001                                          MAIN0115
      GO TO 3002                                                        MAIN0116
3001  WRITE(6,125)                                                      MAIN0117
      GO TO 1                                                           MAIN0118
3002  CONTINUE                                                          MAIN0119
      RHOT=RROOTS(LL)                                                   MAIN0120
44    DOVERH=(DEFL1+DDEFL1*TAUS*RHOT+TERM2*TAUS**2*RHOT**2+TERM3*TAUS** MAIN0121
     1 3*RHOT**3+TERM4*TAUS**4*RHOT**4)/H                               MAIN0122
451   WRITE(6,201) DOVERH                                               MAIN0123
      IF(DOVERH .LT. 1.) GO TO 1001                                     MAIN0124
45    PI1=MU*(2.-XO)/((3.-XO)*PCOL)                                     MAIN0125
      PI2=2.*(3.-3.*XO+XO**2)/((3.-XO)*H)                               MAIN0126
      PI3=(H*BETA/3.)*(1/TANPHI+TANPHI)/(1+BETA/TANPHI)                 MAIN0127
      PI4=(C2/(H*(1.+BETA/TANPHI)))*(2.-2.*XO+XO/((2.*SIN(PHI))**(1./P) MAIN0128
     1 *SIN(PHI)**2))                                                   MAIN0129
      PI5=(C2*BETA*H/(3.+3.*BETA/TANPHI))* (1./(TANPHI**(1.+1./P))+TANP MAIN0130
     1 HI)                                                              MAIN0131
      Z1=PI2/PI1                                                        MAIN0132
      Z2=PI3/PI1                                                        MAIN0133
      Z3=PI4/PI1                                                        MAIN0134
      Z4=PI5/PI1                                                        MAIN0135
      AAA2=TERM2*TAUS**2                                                MAIN0136
      AAA3=TERM3*TAUS**3                                                MAIN0137
      AAA4=TERM4*TAUS**4                                                MAIN0138
      NCOEFS=5                                                          MAIN0139
      GOEFS(1)=(DEFL1-H)                                                MAIN0140
      GOEFS(2)=DDEFL1*TAUS                                              MAIN0141
      GOEFS(3)=AAA2                                                     MAIN0142
      GOEFS(4)=AAA3                                                     MAIN0143
      GOEFS(5)=AAA4                                                     MAIN0144
```

```
      CALL PRPM(COEFS,NCOEFS,FROOTS,GROOTS,POL,NROOTS,IERROR)
      WRITE(6,227) IERROR,NROOTS
      IF (NROOTS .EQ. 0) GO TO 1
      IF (IERROR .NE. 0) GO TO 1
      CALL SORTI(1,4,LLL,FROOTS)
      IF (LLL .EQ. 0) GO TO 3011
      GO TO 3012
 3011 WRITE(6,232)
      GO TO 1
 3012 CONTINUE
      RHOT2=FROOTS(LLL)
      DDEFL2=DDEFL1+2.*TERM2*TAUS*RHOT2+3.*TERM3*(TAUS*RHOT2)**2+
     1 4.*TERM4*(TAUS*RHOT2)**3
      ALPHA2=-(Z1*H+Z2/H+(Z4+Z3*H**2)*DDEFL2/H)/2.
      ALPHA3=-(Z1*H*DDEFL2+Z3*H*DDEFL2**2+ALPHA2*(DDEFL2+Z4+Z3*H*H))/
     1 (3.*H)
      NCOEF=3
      COEF(1)=DDEFL2
      COEF(2)=2.*ALPHA2
      COEF(3)=3.*ALPHA3
      CALL PRPM(COEF,NCOEF,TAUF,CTAUF,POLY,NROOTS,IERROR)
      WRITE(6,227) IERROR,NROOTS
      IF (NROOTS .EQ. 0) GO TO 1
      IF (IERROR .NE. 0) GO TO 1
      CALL SORTA (1,2,KK,TAUF)
      IF (KK .EQ. 0)GO TO 3021
      GO TO 3022
 3021 WRITE(6,208)
      GO TO 1
 3022 CONTINUE
      TAUC=TAUF(KK)
 555  WCVERH=1.+DDEFL2*TAUC/H+ALPHA2*TAUC**2/H+ALPHA3*TAUC**3/H
      WRITE(6,203) WCVERH
      YVER(JSTAV,ISTAV)=WCVERH
      GO TO 1002
 1001 YVER(JSTAV,ISTAV)=DCVERH
```

```
1002  CONTINUE
1000  CONTINUE
      WRITE(6,240) (XOR(I),I=1,18)
      CALL MAX(XOR,18,XMIN,XMAX)
      CALL MAX(YVER,72,YMIN,YMAX)
      DO 1003 I=1,4
      DO 1004 J=1,18
1004  YV(J)=YVER(I,J)
      WRITE(6,241)(YV(II),II=1,18)
1003  CALL DIB2(1,1,1,0,18,0.,XMAX,0.,YMAX,1.,1.,0,0,-1,-1,4,4,XOR,
     1 YV,TIT1,TIT2,TIT3,36,36,36)
      CALL PLTND(NN)
      STOP
      END
```

```
      SUBROUTINE MAX (A,NA,AL,AT)
      DIMENSION A(1)
      WRITE (6,6006)
 6006 FORMAT ('0ENTER MAX')
      AMAX=0.
      DO 10 I=1,NA
      P= ABS(A(I))
      IF(P-AMAX) 10,10,11
   11 AMAX=P
   10 CONTINUE
      B=1.
      J=-1
      IF(AMAX-B) 12,13,13
   13 B=B*10.
      J=J+1
      IF(AMAX-B) 14,13,13
   14 C=B/10.
      I=AMAX+C
      IF (J) 20,20,21
   21 DO 22 K=1,J
   22 I=I/10
      DO 23 K=1,J
   23 I=I*10
      GO TO 20
   12 B=B/10.
      J=J+1
      IF(AMAX-B) 12,15,15
   15 K=J+1
      AT=AMAX+B
      DO 24 L=1,K
   24 AT=AT*10.0
      I=AT
      AT=I
      DO 25 L=1,K
   25 AT=AT/10
      AL=-AT
```

```
      AT=AI                                                             MAX10037
      GO TO 30                                                          MAX10038
   20 AL=-I                                                             MAX10039
      AT=I                                                              MAX10040
   30 RETURN                                                            MAX10041
      END                                                               MAX10042
```

```
      SUBROUTINE DIR2  (NFC,IND,NGRAPH,NGD,NPOINT,XL,XR,YB,YT,DX,DY,
     * N,M,I,J,NX,NY,X,Y,TIT,TITX,TITY,NT,NTX,NTY)
      DIMENSION X(1),Y(1),TIT(1),TITX(1),TITY(1)
      WRITE (6,6007)
 6007 FORMAT ('0ENTER DIR')
      INDA=0
      GO TO (1,2,3,4),IND
    1 CALL SMXYV(0,0)
      GO TO 5
    2 CALL SMXYV(0,1)
      GO TO 5
    3 CALL SMXYV(1,0)
      GO TO 5
    4 CALL SMXYV(1,1)
    5 CONTINUE
      CALL SETMIV(150,100,150,150)
      IF(NFC-1) 10,10,20
   10 NFA=2
      GO TO 30
   20 NFA=4
   30 CALL GRID1V(NFA,XL,XR,YB,YT,DX,DY,N,M,I,J,NX,NY)
      CALL RITE2V(300,125,1000,0,2,NTX,1,TITX,NLAST)
      CALL RITE2V(125,250,1000,90,2,NTY,1,TITY,NLAST)
      CALL RITE2V(250,925,1000,0,2,NT,1,TIT,NLAST)
      CALL INCRV(8,4)
      NAU=NGRAPH+NGD
      DO 7 II=1,NAU
      NAUX=NPOINT-1
      DO 8 K=1,NAUX
      IAUX=(II-1)*NPOINT+K
      X1=X(K)
      X2=X(K+1)
      Y1=Y(IAUX)
      Y2=Y(IAUX+1)
      IF(Y1-YT) 100,100,101
  100 IF(Y2-YT) 110,110,103
```

```
  103 X2=(X2-X1)*(YT-Y1)/(Y2-Y1)+X1                          DIB20037
      Y2=YT                                                  DIB20038
      GO TO 110                                              DIB20039
  101 IF(Y2-YT) 104,104,105                                  DIB20040
  104 X1=(X2-X1)*(YT-Y1)/(Y2-Y1)+X1                          DIB20041
      Y1=YT                                                  DIB20042
      GO TO 110                                              DIB20043
  105 INDA=1                                                 DIB20044
  110 CONTINUE                                               DIB20045
      IF(Y1-YB) 200,201,201                                  DIB20046
  200 IF(Y2-YB) 205,203,203                                  DIB20047
  205 INDA=1                                                 DIB20048
      GO TO 210                                              DIB20049
  203 X1=(X2-X1)*(YB-Y1)/(Y2-Y1)+X1                          DIB20050
      Y1=YB                                                  DIB20051
      GO TO 210                                              DIB20052
  201 IF(Y2-YB) 204,210,210                                  DIB20053
  204 X2=(X2-X1)*(YB-Y1)/(Y2-Y1)+X1                          DIB20054
      Y2=YB                                                  DIB20055
  210 CONTINUE                                               DIB20056
      IF(INDA) 303,303,302                                   DIB20057
  303 IF(II-NGRAPH) 300,300,301                              DIB20058
  300 CALL LINEV(NXV(X1),NYV(Y1),NXV(X2),NYV(Y2))            DIB20059
      CALL LINEV(NXV(X1),NYV(Y1),NXV(X2),NYV(Y2))            DIB20060
      GO TO 302                                              DIB20061
  301 CALL DOTLNV(NXV(X1),NYV(Y1),NXV(X2),NYV(Y2))           DIB20062
      CALL DOTLNV(NXV(X1),NYV(Y1),NXV(X2),NYV(Y2))           DIB20063
  302 INDA=0                                                 DIB20064
    8 CONTINUE                                               DIB20065
    7 CONTINUE                                               DIB20066
      RETURN                                                 DIB20067
      END                                                    DIB20068
```

```
      SUBROUTINE SORT1(M,N,L,A)                                         SOR10001
      DIMENSION  A(4)                                                   SOR10002
      K=0                                                               SOR10003
      GO TO 1                                                           SOR10004
      ENTRY SORT2(N)                                                    SOR10005
      M=1                                                               SOR10006
      K=1                                                               SOR10007
      GO TO 1                                                           SOR10008
      ENTRY SORT3(M,N)                                                  SOR10009
      K=2                                                               SOR10010
1     NM1=N-1                                                           SOR10011
      DO 60 I=1,NM1                                                     SOR10012
      JJ=N-I                                                            SOR10013
      DO 50 J=1,JJ                                                      SOR10014
      IF (K .EQ. 2 .AND. ABS(A(J)) .GT. ABS(A(J+1)) .OR. K .NE. 2 .AND. SOR10015
     1 A(J) .GT. A(J+1)) GO TO 10                                       SOR10016
      GO TO 50                                                          SOR10017
10    T=A(J)                                                            SOR10018
      A(J)=A(J+1)                                                       SOR10019
      A(J+1)=T                                                          SOR10020
50    CONTINUE                                                          SOR10021
60    CONTINUE                                                          SOR10022
      IF (K .NE. 0) RETURN                                              SOR10023
      ENTRY FIRSTP(N,M,L)                                               SOR10024
      L=0                                                               SOR10025
      DO 40 I=M,N                                                       SOR10026
      IF (A(I) .GE. 0.) GO TO 20                                        SOR10027
40    CONTINUE                                                          SOR10028
      RETURN                                                            SOR10029
20    L=I                                                               SOR10030
      RETURN                                                            SOR10031
      END                                                               SOR10032
```

```
      SUBROUTINE  SORT4(M,N,L,A)                                        SOR40001
      DIMENSION A(2)                                                    SOR40002
      K=0                                                               SOR40003
      GO TO 1                                                           SOR40004
      ENTRY SORT5                                                       SOR40005
      M=1                                                               SOR40006
      K=1                                                               SOR40007
      GO TO 1                                                           SOR40008
      ENTRY SORT6(M,N)                                                  SOR40009
      K=2                                                               SOR40010
1     NM1=N-1                                                           SOR40011
      DO 60 I=1,NM1                                                     SOR40012
      JJ=N-I                                                            SOR40013
      DO 50 J=1,JJ                                                      SOR40014
      IF (K .EQ. 2 .AND. ABS(A(J)) .GT. ABS(A(J+1)) .OR. K .NE. 2 .AND. SOR40015
     1 A(J) .GT. A(J+1)) GO TO 10                                       SOR40016
      GO TO 50                                                          SOR40017
10    T=A(J)                                                            SOR40018
      A(J)=A(J+1)                                                       SOR40019
      A(J+1)=T                                                          SOR40020
50    CONTINUE                                                          SOR40021
60    CONTINUE                                                          SOR40022
      IF (K .NE. 0) RETURN                                              SOR40023
      ENTRY FIRST(N,M,L)                                                SOR40024
      L=0                                                               SOR40025
      DO 40 I=M,N                                                       SOR40026
      IF (A(I) .GE. 0.) GO TO 20                                        SOR40027
40    CONTINUE                                                          SOR40028
      RETURN                                                            SOR40029
20    L=I                                                               SOR40030
      RETURN                                                            SOR40031
      END                                                               SOR40032
```

PAGE 12

3.0	5.0625	0.158	0.0635	.279	76.08	35900.0	1.0	470.	DATA0001
3.0	5.0625	0.16	.0643	.279	98.00	35900.0	1.0	470.	DATA0002
3.0	5.0625	0.16	.0643	.279	120.00	35900.0	1.0	470.	DATA0003
3.0	5.0625	0.16	.0643	.279	134.08	35900.0	1.0	470.	DATA0004
3.0	5.0625	0.16	.0644	.279	142.00	35900.0	1.0	470.0	DATA0005
3.0	5.0625	0.16	.0644	.279	152.40	35900.0	1.0	470.0	DATA0006
3.0	5.0625	0.16	.0644	.279	160.00	35900.0	1.0	470.0	DATA0007
3.0	5.0625	0.159	.0638	.279	165.06	35900.0	1.0	470.	DATA0008
3.0	5.0625	0.159	.0638	.279	170.00	35900.0	1.0	470.	DATA0009
3.0	5.0625	0.159	.0638	.279	180.06	35900.0	1.0	470.	DATA0010
3.0	5.0625	0.159	.0638	.279	197.06	35900.0	1.0	470.	DATA0011
3.0	5.0625	0.159	.0638	.279	208.06	35900.0	1.0	470.	DATA0012
3.0	5.0625	0.162	.0647	.279	233.00	35900.0	1.0	470.	DATA0013
3.0	5.0625	0.158	0.0635	.279	245.08	35900.0	1.0	470.	DATA0014
3.0	5.0625	0.162	.0647	.279	258.00	35900.0	1.0	470.	DATA0015
3.0	5.0625	0.142	.0647	.279	270.00	35900.0	1.0	470.	DATA0016
3.0	5.0625	0.153	0.0635	.279	282.08	35900.0	1.0	470.	DATA0017

PAGE 13

Thesis 134540
S6795 Stefanidis
Viscoplastic behavior
of plates with finite
deflections.